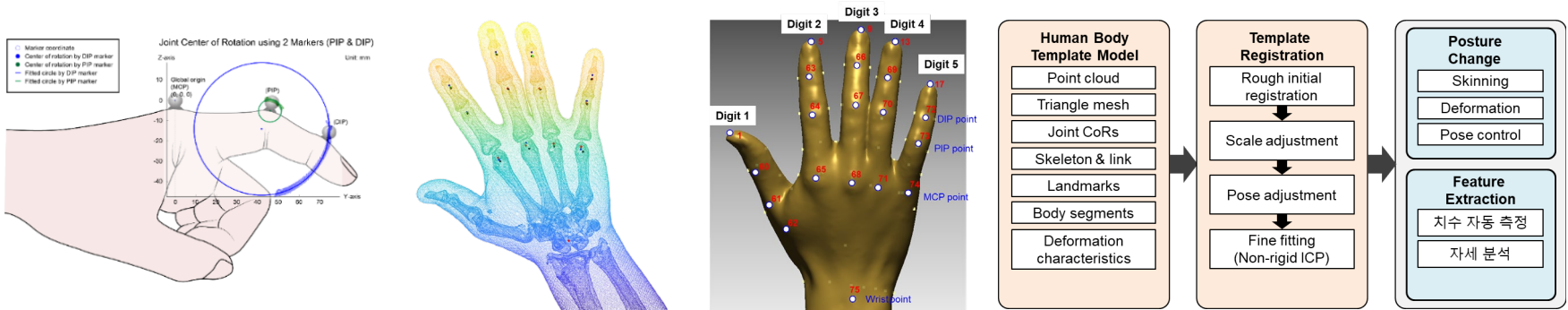


Development of Hand Template Model for Ergonomic Product Design



정하영¹, 이원섭², 정성욱¹, 유희천¹

¹ 포항공과대학교 산업경영공학과

² 한동대학교 ICT창업학부

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- Template Model 구성 요소 분석
- Deformable Hand Template Model (HTM) 개발
- Deformable HTM Applications

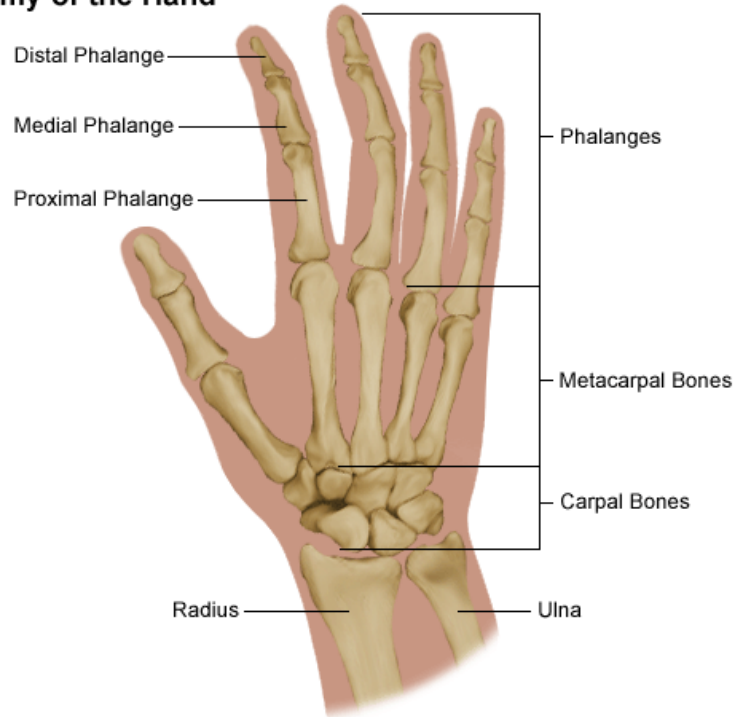
4. 토 의

연구 배경 (1/2)

- 손은 5개의 손가락 및 18개의 관절(27 자유도)로 구성된 정교한 인체 기관
- 손은 정교하고 복잡한 동작을 요구하는 다양한 manual work 수행 시 활용됨

손 전반 형상 및 관절 구성

Anatomy of the Hand



다양한 handle design

Drill



의료기기(초음파 probe)



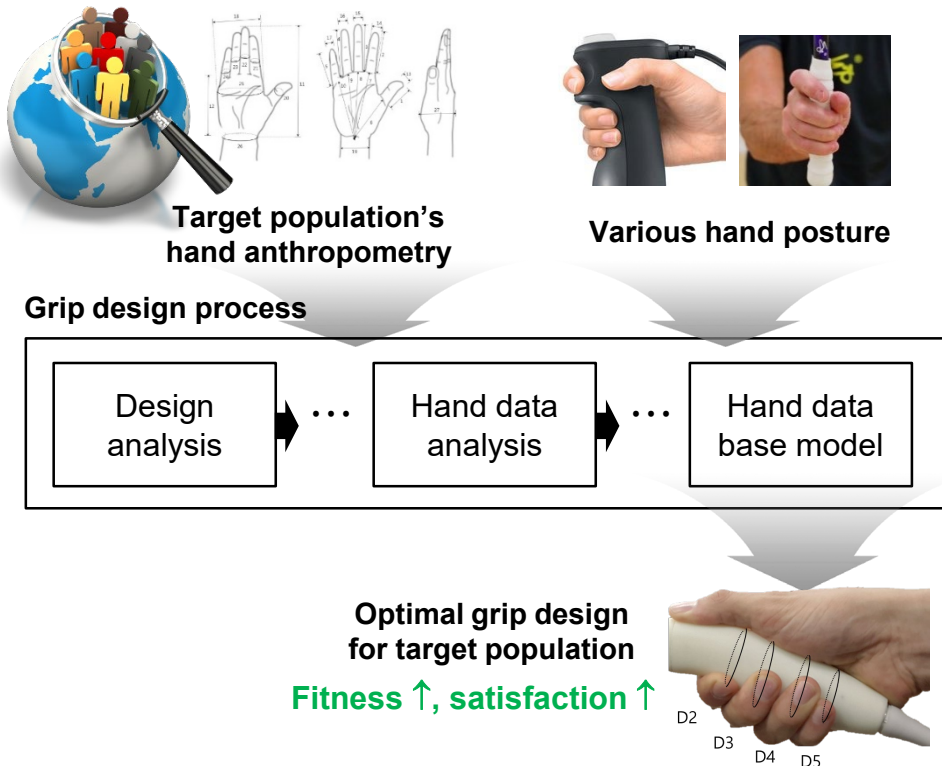
청소기 handle



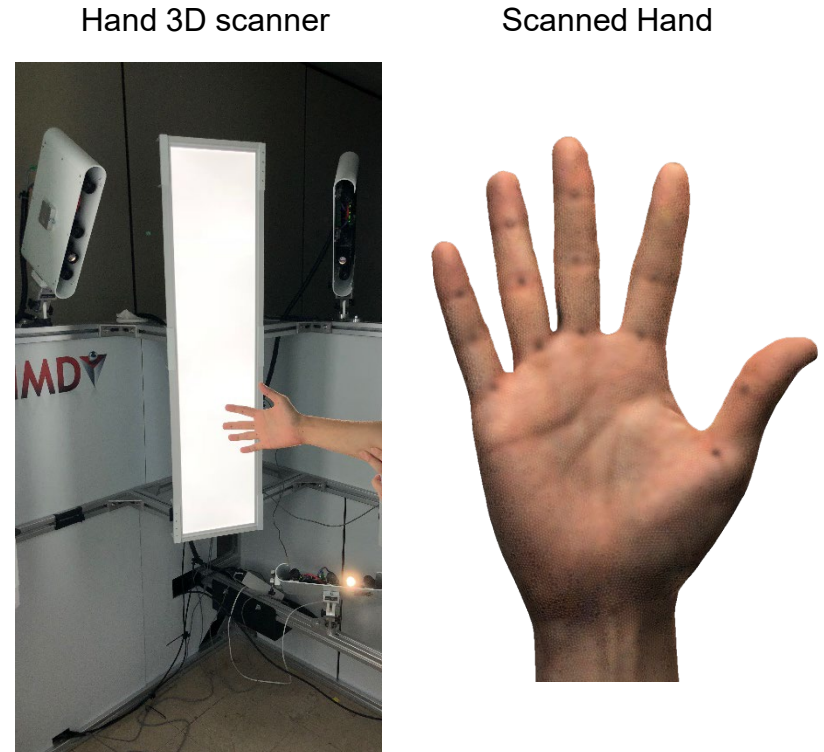
연구 배경 (2/2)

- 인간공학적 handle 및 hand tool 개발을 위해 손 파지 자세 및 형상 분석 필요
- 3D scanner를 이용한 3차원 손 측정 및 형상 분석이 수행됨

인간공학적 handle/hand tool 설계



3D scanner를 이용한 3차원 손 scan



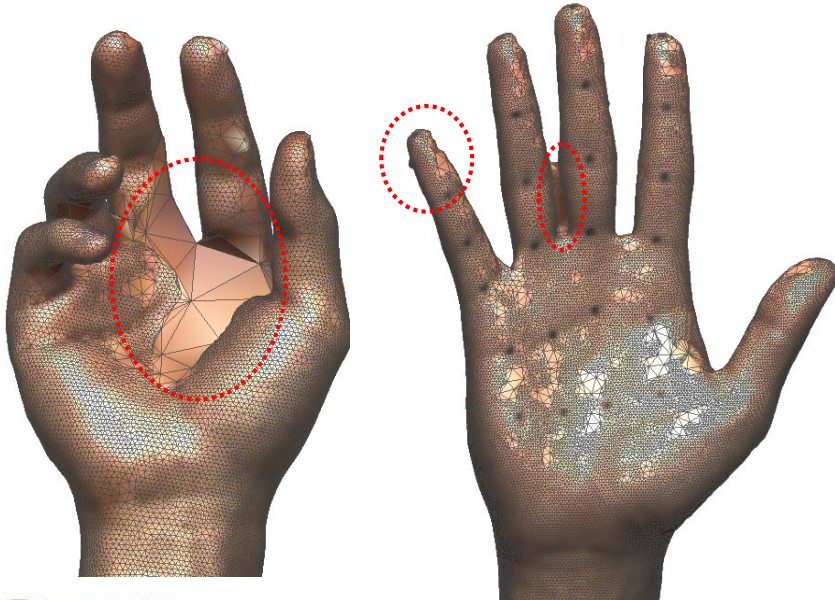
연구 필요성

❑ 3D scan을 통한 손 형상 재구성의 어려움

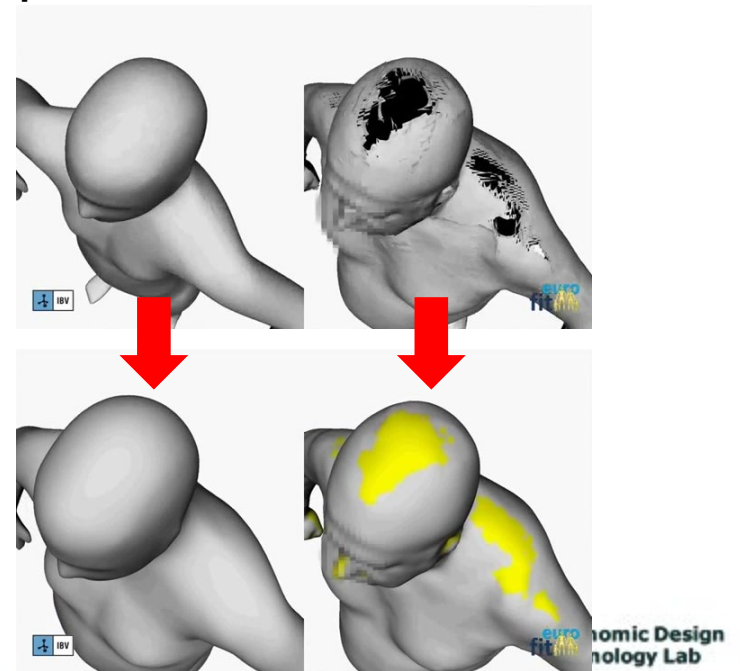
- 손의 얇고 긴 형태적인 특성으로 3D scan으로 온전한 형상 획득이 어려움
- 편 자세 외 파지 자세 등은 3D scan 시 가려져 측정이 불가능함
- 3D scan 시 일부 접힘 부위 missing으로 형상 보강 및 후처리 필요

❑ 손 3D scan의 한계를 보완하기 위해 hand template model을 이용한 3차원 인체 형상 기술의 활용 필요

낮은 품질의 손 3D scan 예



Template model을 이용한 형상 보강 예



기존 연구의 한계점

- 기존 3차원 인체형상 기술 및 template model은 **computer graphics 분야**에서 자연스러운 3D animation 구현 등에 주로 활용됨
 - ⇒ 3D 인체 형상 기술을 파지류 제품 설계에 적용 활성화 필요
 - ⇒ 동작 변화에 따른 체표 길이, 둘레, 부피 변화 등 인체 치수 변형 특성 분석 기술 고도화 필요
- 기존 template model은 full body model로 **손의 특성에 최적화된 모델은 부족함**

Computer graphics의 HBTM application 예

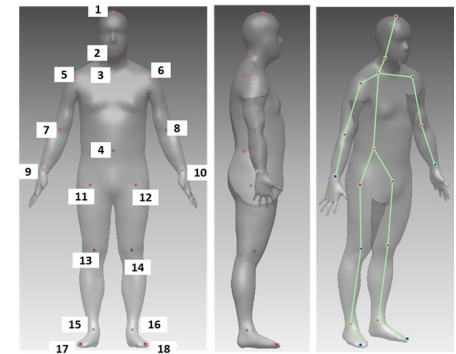
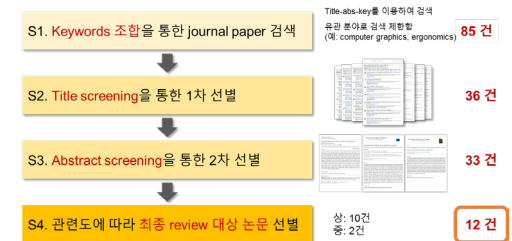


형상 변형 특성을 고려한 인간공학적 제품 설계 예



인간공학적 제품 설계를 위한 3차원 Deformable Hand Template Model 개발

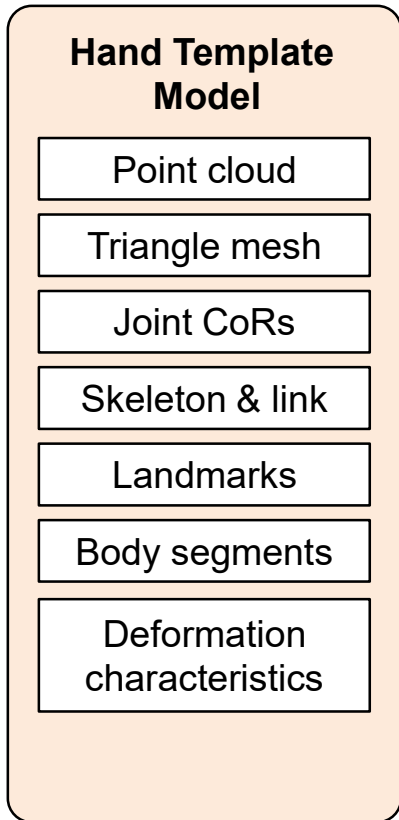
1. Human Template Model 유관 문헌 조사
2. Human Template Model 구성요소 분석
3. 3D Hand Template Model 조사 및 개발
4. Deformable HTM Application 고찰



Big Picture: Template Model 기반 제품 설계 기술

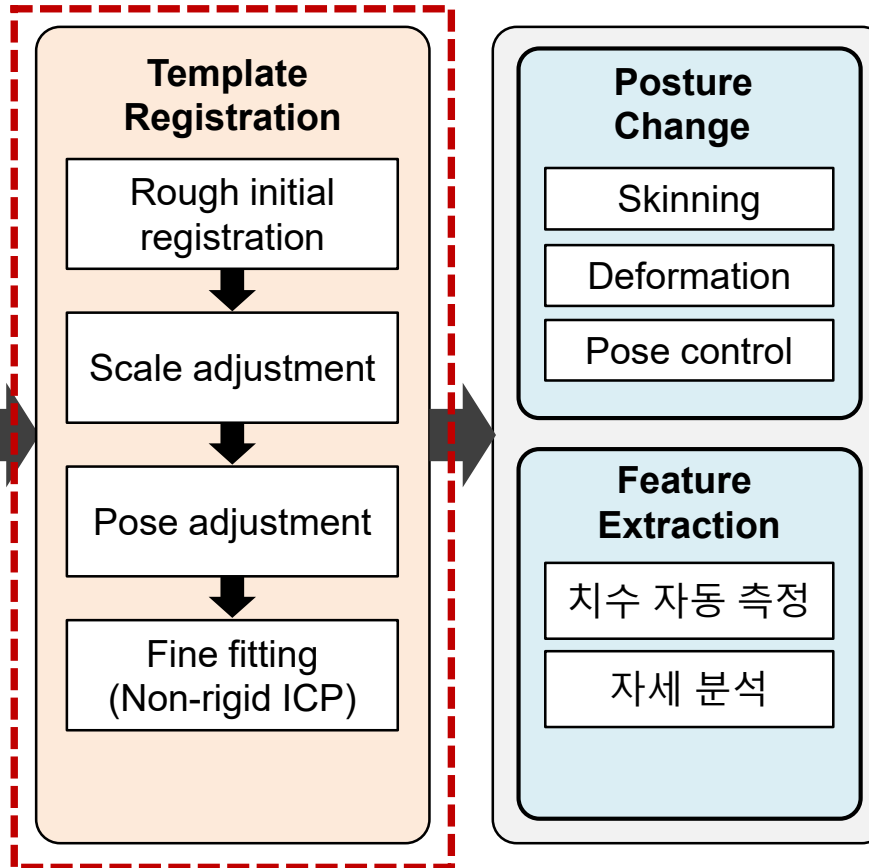
Phase 1

Template Model 개발



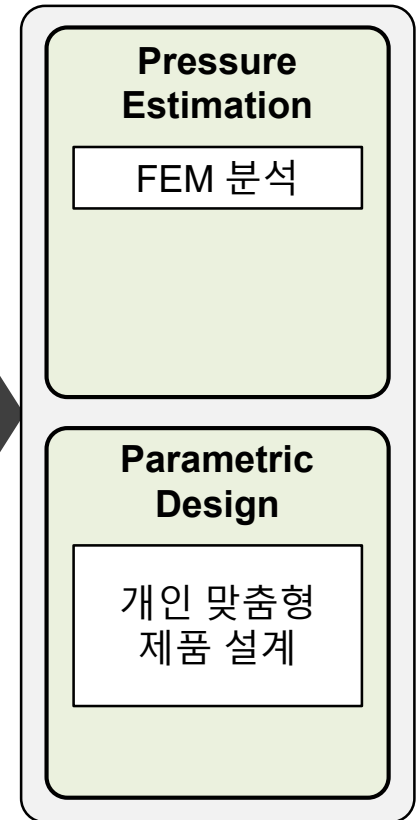
Phase 2

Digital Human Modeling 기술 개발
(Registration, Deformation, Posture Change)

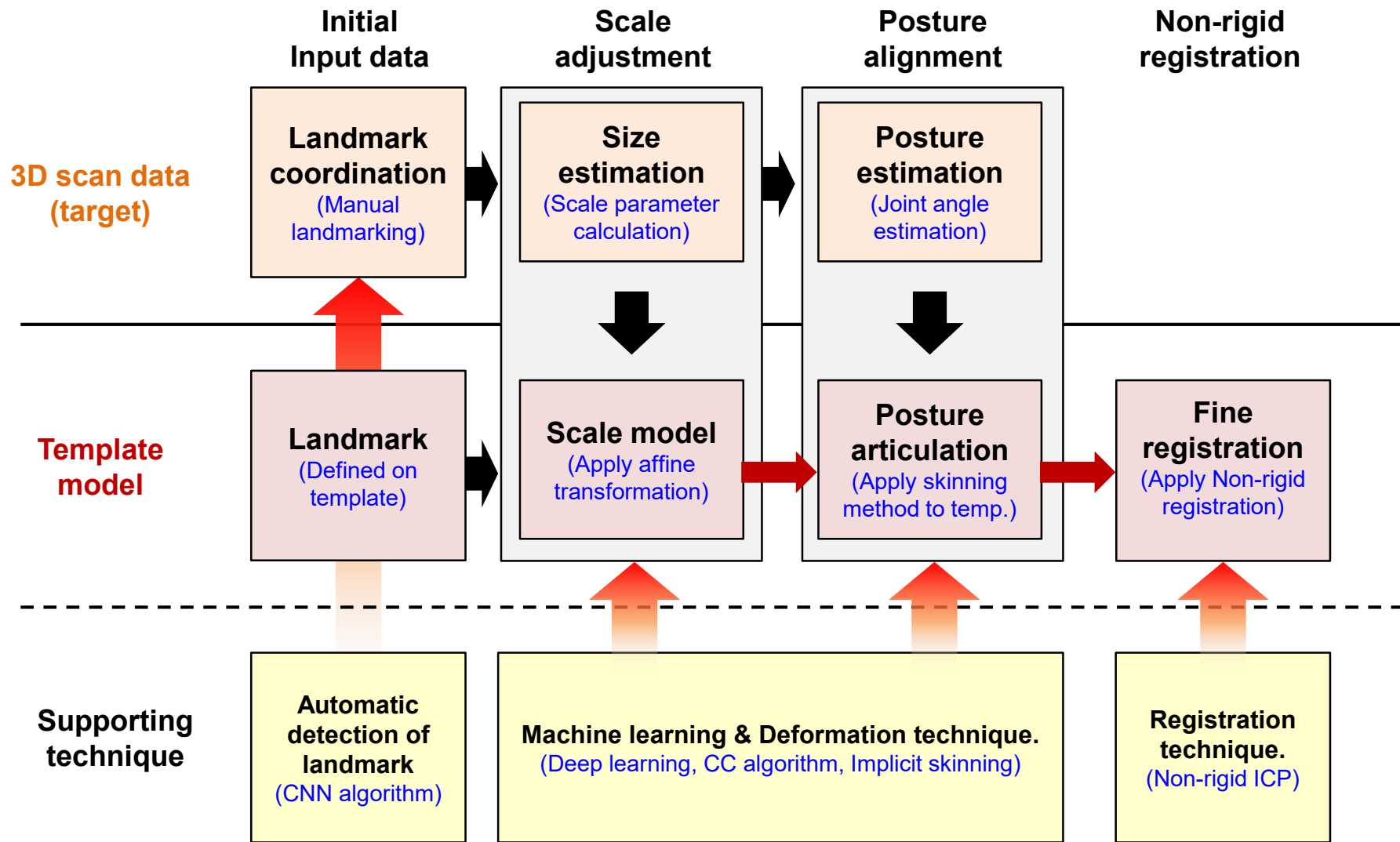


Phase 3

최적 설계 기술 개발



Big Picture: Registration 기술 개발



Source: Allen et al., 2003; Angelov et al., 2005; Pishchulin et al., 2017

Template Model 논문 조사: 방법

- ❑ 문헌 조사 site: www.scopus.com
- ❑ 검색 조건: title, abstract, keyword
- ❑ 검색 분야별 keyword
 - **공통 Keyword:** 3D scan, 3D Human, Body scanning, 3D human body, 3D hand
 - **Template model 관련:** Meshed human model, mesh animation, template model, body segment, skeleton estimation, linear blend skinning, skinning mesh
 - **검색 식 구성 방법:** Title-abs-key((공통 Keyword) AND (세부분야 Keyword))
 - **검색 식:** TITLE-ABS-KEY(("3D scan" or "3D Human" or "Body scanning" or "3D human body" or "3D body scan" or "3D hand") and ("meshed human model" or "mesh animation" or "template model" or template or "skeleton animation" or "linear blend skinning" or "skinning mesh" or skinning))

Template Model 논문 조사: 결과

S1. **Keywords 조합**을 통한 journal paper 검색

Title-abs-key를 이용하여 검색

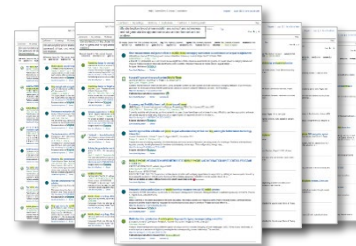
유관 분야로 검색 제한함

(예: computer graphics, ergonomics)

85 건



S2. **Title screening**을 통한 1차 선별



36 건



S3. **Abstract screening**을 통한 2차 선별



33 건



S4. 관련도에 따라 **최종 review 대상 논문 선별**

상: 11건

중: 2건

13 건

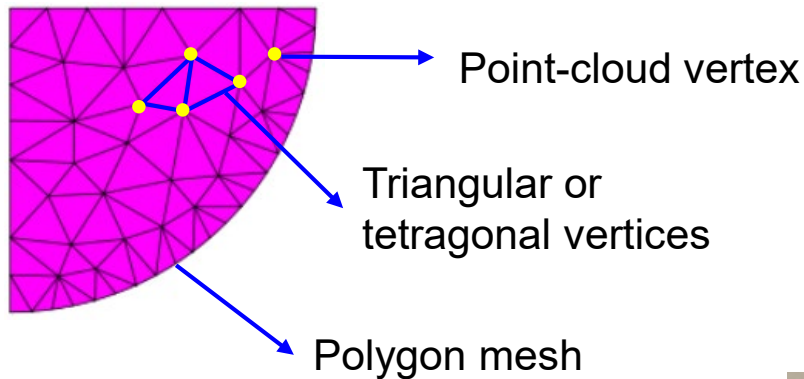
Template Model 논문 List

No.	Year	Author(s)	Title	Institute	중요도
1	2012	Ghosh et al.	From Deformations to Parts: Motion-based Segmentation of 3D Objects	Max Planck Institute (MPI)	상
2	2014	Loper et al.	MoSh: Motion and Shape Capture from Sparse Markers	Max Planck Institute (MPI)	상
3	2014	Tsoil	Modeling the Human Body in 3D: Data Registration and Human Shape Representation	Max Planck Institute (MPI)	상
4	2011	Tsoil and Black	Shape- and Pose-Invariant Correspondences using Probabilistic Geodesic Surface Embedding	Max Planck Institute (MPI)	상
5	2014	Tsoil et al.	Model-based Anthropometry: Predicting Measurements from 3D Human Scans in Multiple Poses	Max Planck Institute (MPI)	상
6	2014	Jacobson et al.	Bounded Biharmonic Weights for Real-Time Deformation	Interactive Geometry Lab, ETH IGL, Switzerland	상
7	2004	O. Sorkine et al.	Laplacian Surface Editing	Interactive Geometry Lab, ETH IGL, Switzerland	상
8	-	K. Takayama et al.	Sketch-Based Generation and Editing of Quad Meshes	Interactive Geometry Lab, ETH IGL, Switzerland	상
9	2014	Jacobson et al.	Bounded Biharmonic Weights for Real-Time Deformation	IBV, Spain	상
10	2015	Reed et al.	Statistical Prediction of Body Landmark Locations on Surface Scans	UMTRI, US	상
11	2017	Romero et al.	Embodied Hands: Modeling and Capturing Hands and Bodies Together	ACM Transactions on Graphic / MPI - PS	상
12	2004	Moccozet et al.	Animatable Human Body Model Reconstruction from 3D Scan Data using Templates	MIRA Lab, University of Geneva, Switzerland	중
13	2011	Yeh et al.	Template-Based 3D Model Fitting Using Dual-Domain Relaxation	National Cheng-Kung University	중

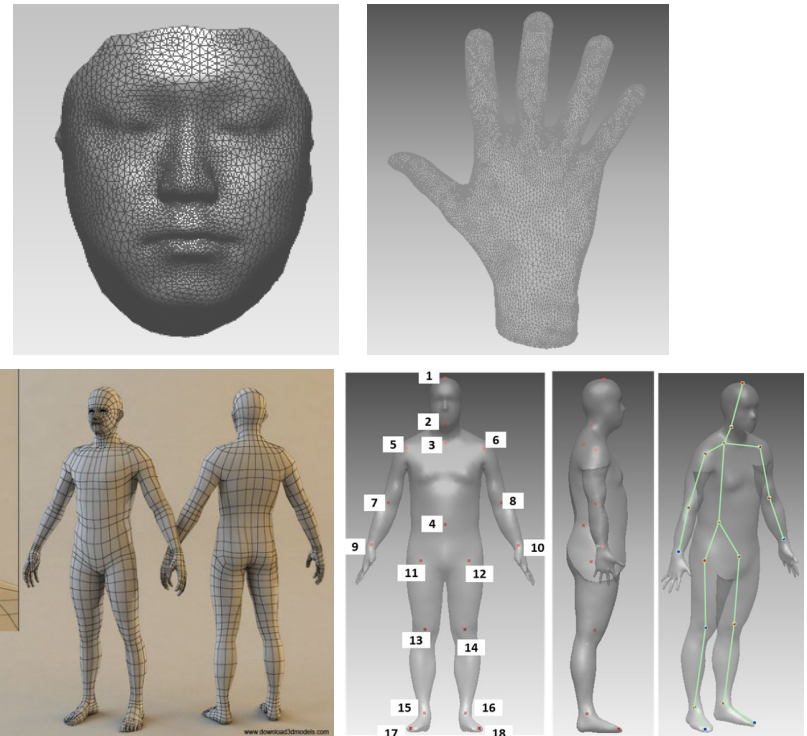
Human Body Template Model (HBTM)

- Template model은 정교한 human surface mesh model의 복합체
- Bone(CoR 포함), skin, landmark 등으로 구성되며 각 요소별 특성 정보 포함
- Skin 및 bone은 triangle의 복합체로 구성된 polygon mesh (vertex, node 포함)

Polygon mesh 구성 요소



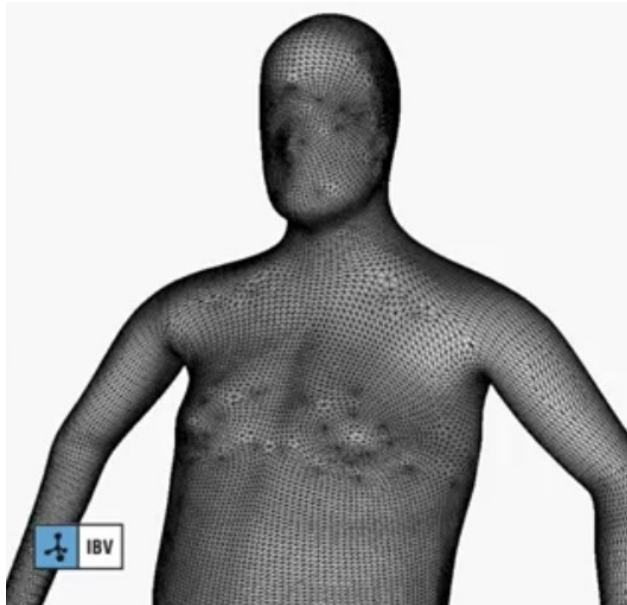
Human surface mesh model 예



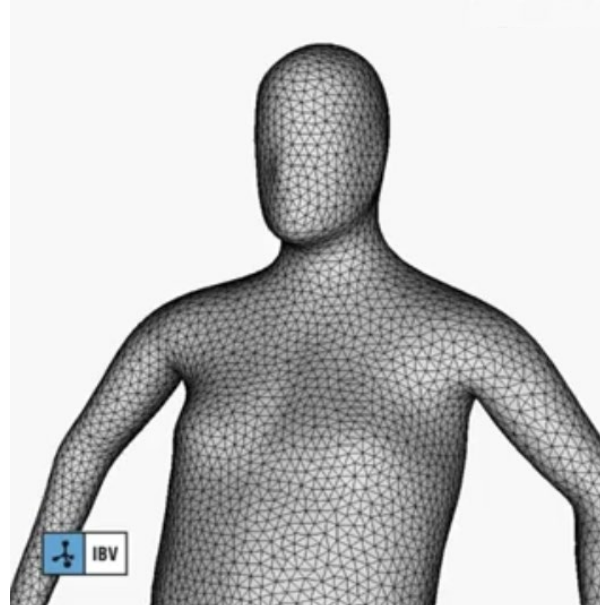
Template Model 구성 요소: Surface Mesh

- 적정 수의 vertex 및 node: 3D registration 효율을 고려한 적정 수 도출
- 인체 기준점(landmark): 효율적인 인체 치수 측정을 위한 기준점

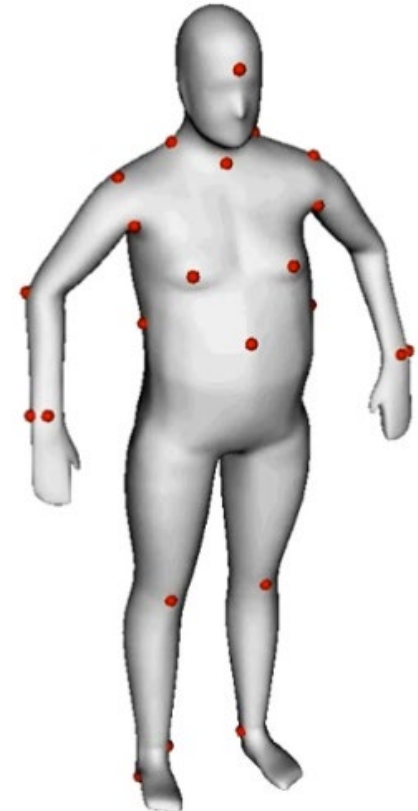
High-resolution HBTM



Low-resolution HBTM



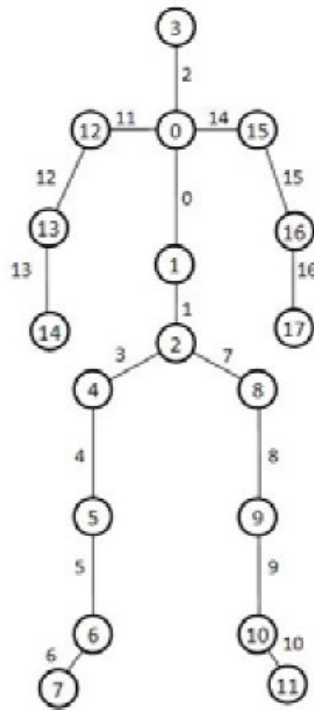
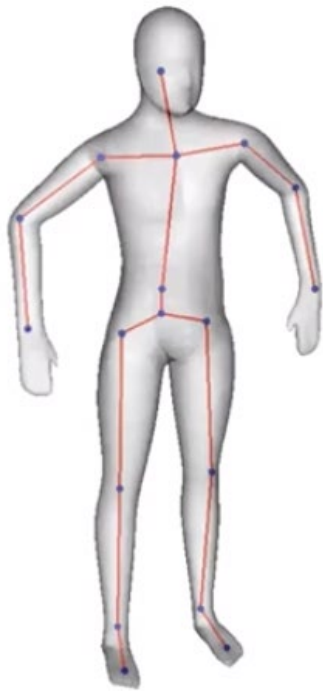
Landmark 예시



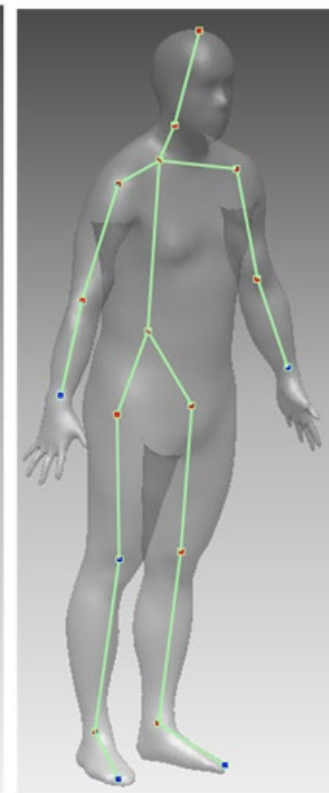
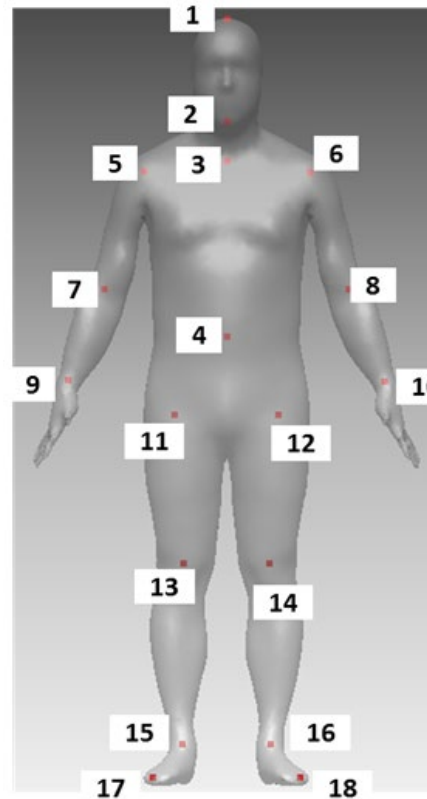
Template Model 구성 요소: Skeleton & Joint

□ **Skeleton** 및 **joint center**: 인체 형상 및 자세를 고려한 skeleton link 생성

IBV, Spain



EDT Lab (POSTECH)



Template Model 구성 요소: Body Segment

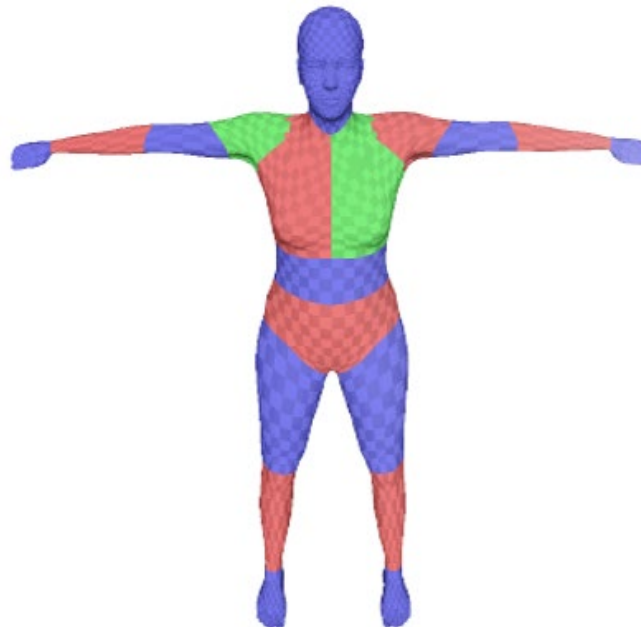
□ **Body segmentation:** 자세 변형 시 신체 부위별 변형 특성 고려

Segmentation of body parts
(# segment = 16)



IBV, Spain

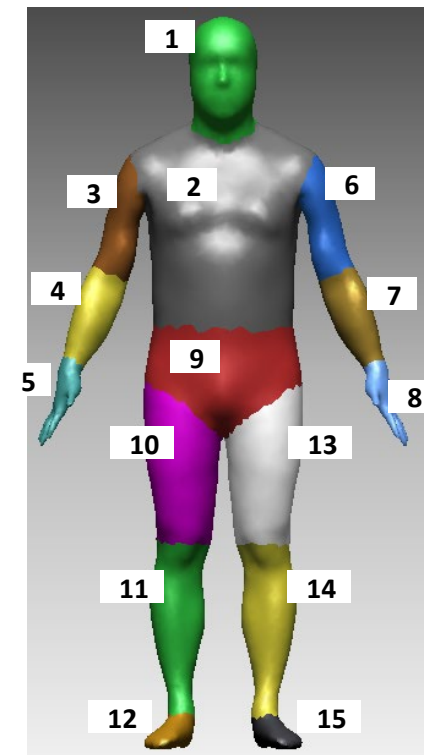
Segmentation of body parts
(# segment = 19)



Template: T^*

Perceiving Systems Lab, Germany

Segmentation of body parts
(# segment = 15)



EDT Lab (POSTECH)

Hand Model 논문 List

No.	Year	Author(s)	Title	Source / Institute	중요도
1	2014	Endo et al.	Dhaiba: Development of Virtual Ergonomics Assessment System with Human Models	AIST (Japan)	상
2	2017	Romero et al.	Embodied Hands: Modeling and Capturing Hands and Bodies Together	ACM Transactions on Graphic / MPI – PS	상
3	2011	Buczekl et al.	Kinematic performance of a six degree-of-freedom hand model (6DHand) for use in occupational biomechanics	Journal of Biomechanics	상
4	2011	Oikonomidis et al.	Full DOF tracking of a hand interacting with an object by modeling occlusions and physical constraints	International conference on Computer Vision (ICCV)	중
5	2013	Sridhar et al.	Interactive Markerless Articulated Hand Motion Tracking using RGB and Depth Data	International conference on Computer Vision (ICCV)	중
6	2016	Tkach et al.	Sphere-meshes for real-time hand modeling and tracking.	ACM Transactions on Graphics	중
7	2014	Schmidt et al.	DART: Dense Articulated Real-Time Tracking	In Robotics: Science and Systems	중
8	2016	Tzionas et al.	Capturing Hands in Action using Discriminative Salient Points and Physics Simulation	International Journal of Computer Vision (IJCV)	중
9	2015	Khamis et al.	Learning an Efficient Model of Hand Shape Variation from Depth Images	In IEEE Conference on Computer Vision and Pattern Recognition (CVPR)	중
10	2015	Oberweger et al.	Training a Feedback Loop for Hand Pose Estimation	International conference on Computer Vision (ICCV)	중

Dhaiba Hand Model: AIST (Endo et al., 2014)

- ❑ 3D scan 및 motion marker data를 이용하여 **deformable, reposable** 모델 생성
- ❑ Grasp comfortability에 기반한 **optimal grip 추정 방법** 적용 및 **접촉면 분석**

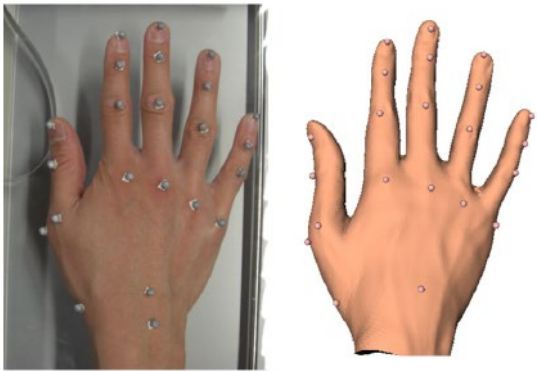


Fig. 4: Reconstruction of individual hand models from scanned hand images (reprinted from (Miyata 2011)).

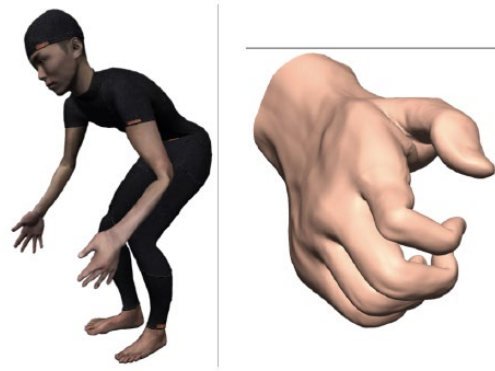


Fig. 2: Postures of the Dhaiba models. (a) DhaibaBody and (b) DhaibaHand.

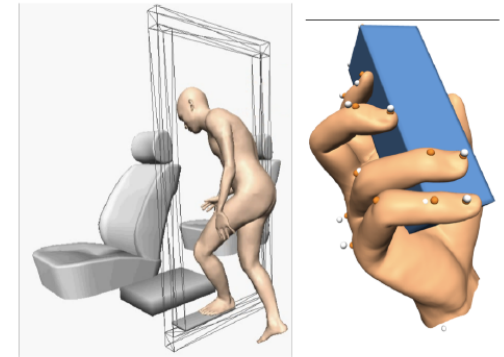


Fig. 7: Reconstructed postures of the Dhaiba models from marker trajectories obtained from the motion capture. White points show the measured markers and orange points show the feature points on the skin surface model.

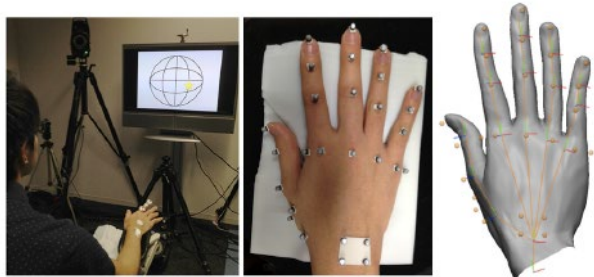


Fig. 5: Reconstruction of individual hand models from marker trajectories obtained from the motion capture (reprinted from (Endo 2014-1)).

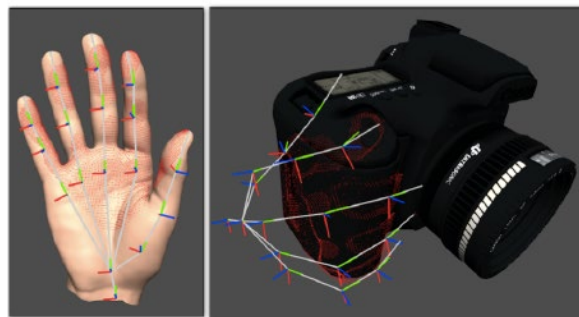


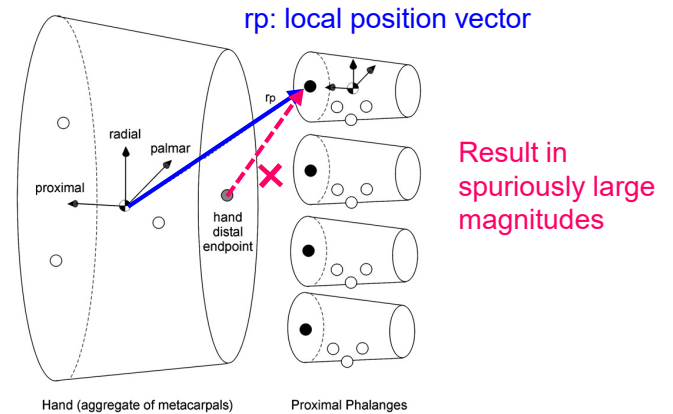
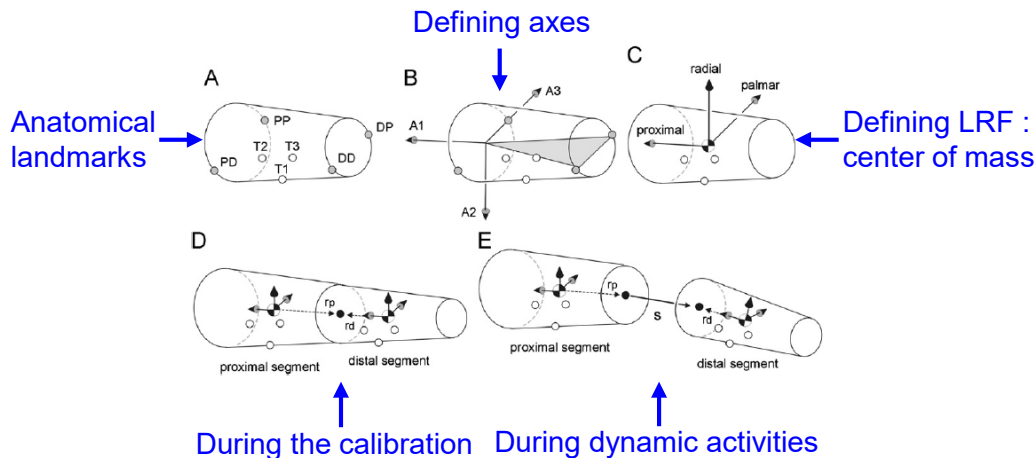
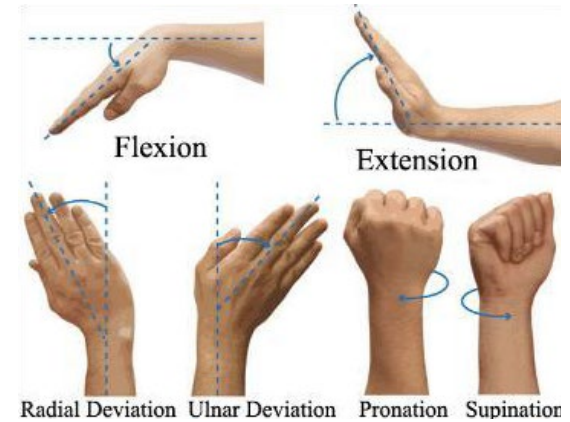
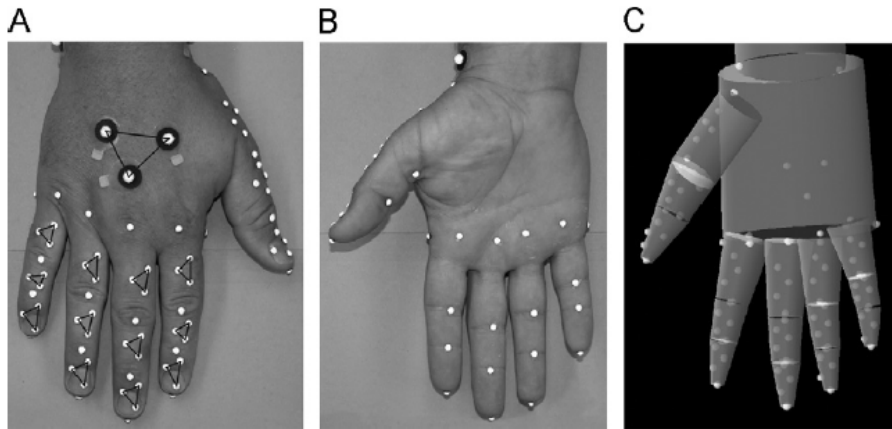
Fig. 11: Contact region for the grasp posture. Red points show the contact points.



Fig. 8: Results of the posture reconstruction by the simulation using the spring and damper models. Upper left and upper middle figure show the posture reconstruction process. The product models are gradually magnified in the simulation so as to avoid the collision in the early stage of the simulation.

6 DoF Hand Model: Buczek et al., 2011

- Hand model 개발 시 손 segment를 기준으로 (1) flexion/extension, (2) ulnar/radial deviation, (3) pronation/supination, (4) radial, (5) palmar, (6) proximal translation 고려



Metacarpals

Embodied Hand Model: MPI (Romero et al., 2017)

- 다양한 손 자세 및 손 형상을 학습하여 낮은 품질의 scan data에도 높은 정확도 및 성능으로 target scan data에 정렬되는 hand template model 및 인체형상 기술 개발
- 기존 전신 정렬 기술(Loper et al., 2015)에 손의 특성을 분석 및 적용하여 전신 및 손을 함께 처리할 수 있는 인체형상 기술 제안

Hand posture & shape learning



Fig. 5. Hand capture protocol. Each of the 31 subjects performed most of the 51 hand poses shown here. Images here are shown from multiple subjects.



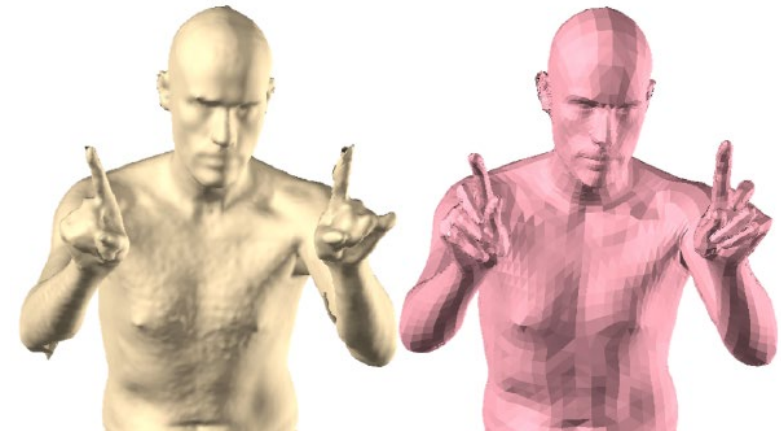
Fig. 7. Examples of the captured "flat-hand" pose for various subjects. The top row shows some of the captured scans, while the bottom row shows the corresponding mesh alignments with pink color.

High quality hand template registration 예

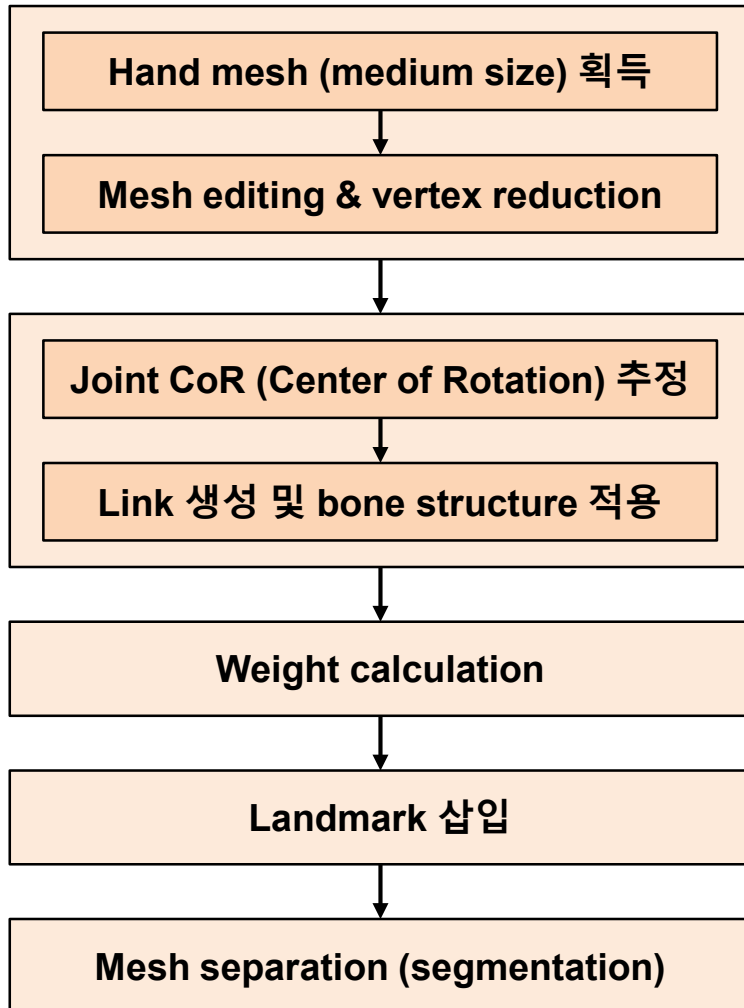


Original scan

Registered template



Hand Template Model (HTM) 개발 절차

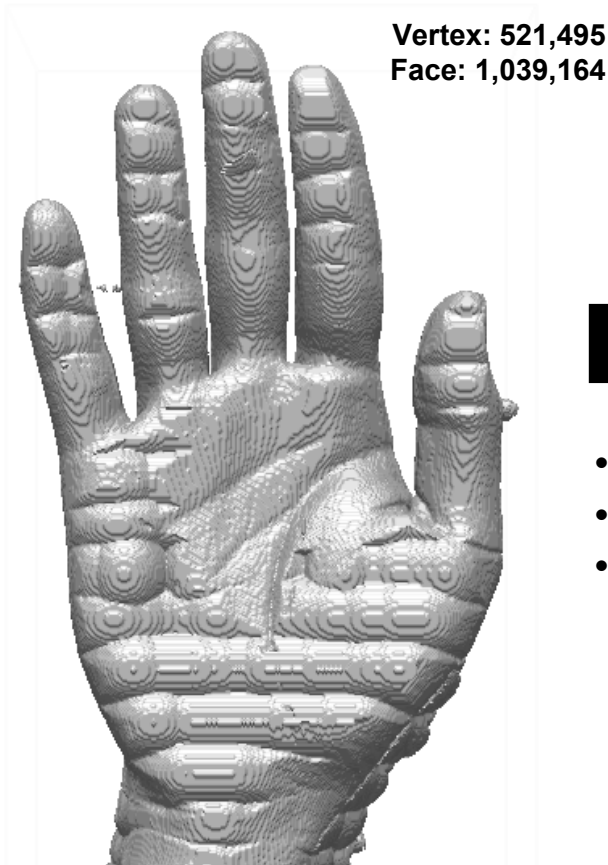


- Size Korea 2010 손직선길이 기준 medium size male에 해당하는 손 scan 및 후처리
- Vertex reduction: target vertex 15,000 ~ 20,000 되도록 mesh reduction 수행
- 선행 연구(Lim, 2018) 결과를 이용하여 CoR 도출 (Delonge Kasa Method 활용, fixed CoR 도출)
- Link model 생성 및 hand bone 적용
- Weight: hand mesh 상의 vertex의 상대적인 중요도
- CoR로부터 거리를 기반으로 계산됨
- Blender S/W를 이용하여 연산
- 손등: 59개 landmark
- 손바닥: 16개 landmark
- 16개 hand region segmentation

HTM 개발: Surface Model

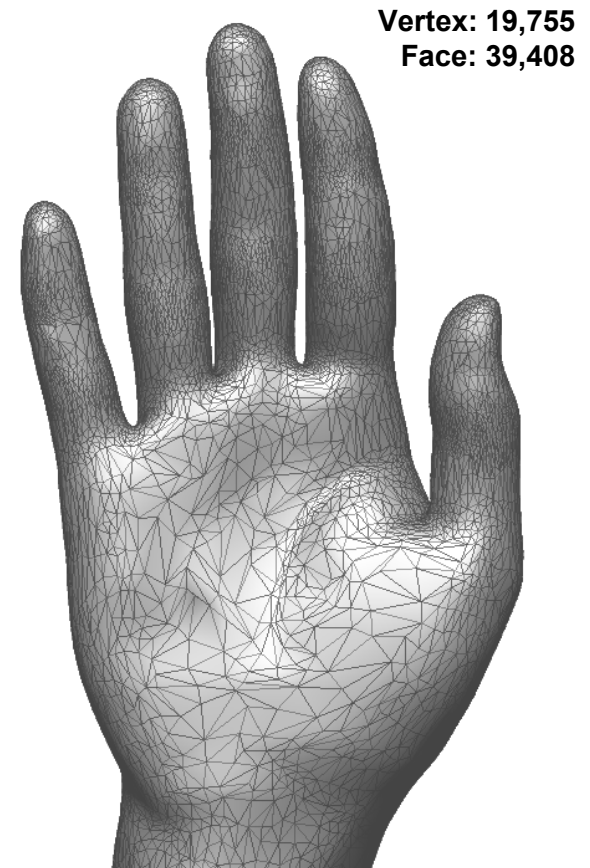
□ 평균 크기(50th%ile)의 3D hand scan을 가공하여 hand template 개발

Original CT-Scan (Medium size)



- Hole filling
- Smoothing
- Symmetrizing

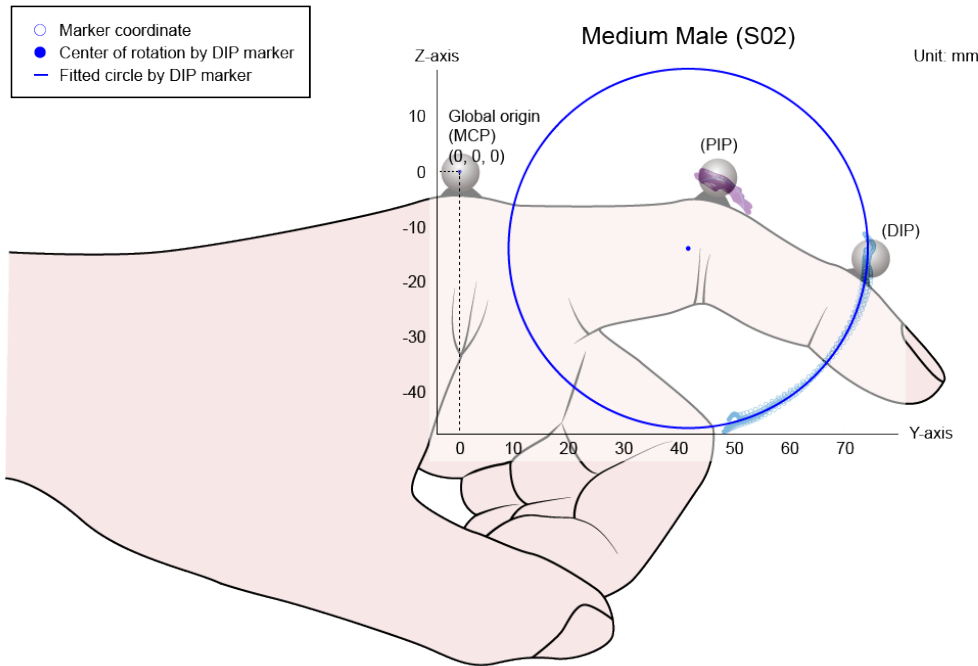
Hand Template



HTM 개발: Joint Center of Rotation

- 정교한 **body & hand joint CoR 정의**(fixed & instantaneous joint CoR)
- **Simplified body & hand link model** 정의 가능

Accurate hand joint CoR

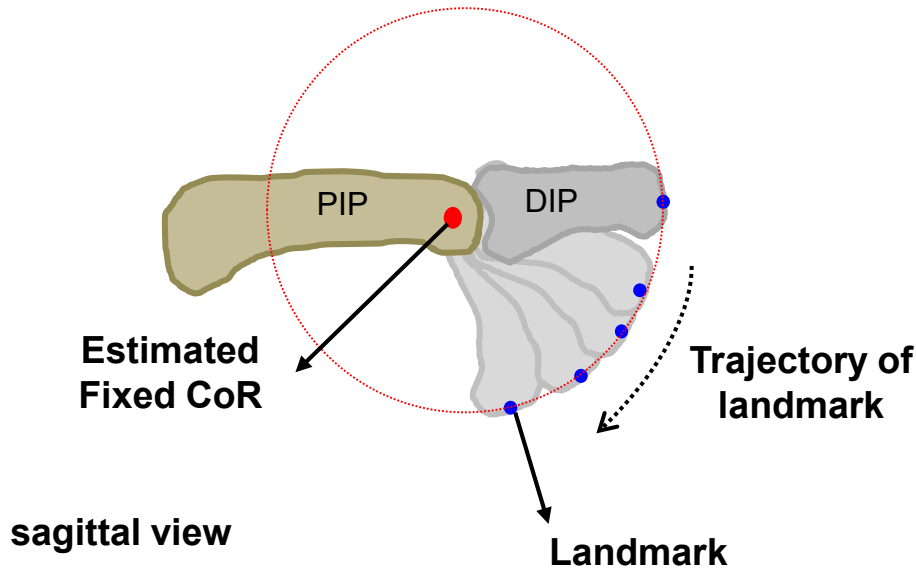


Hand joint CoR 적용 예



HTM 개발: Joint Center of Rotation 추정 방법(Lim et al. 2018)

- Delong-Kasa 방법 적용: **landmark trajectory**를 이용하여 **fixed joint CoR 추정**
- CoR estimation steps
 - S1. 10가지 **natural grasping** 자세의 bone surface data에서 **동일 지점의 landmark 선정**
 - S2. bone surface 상의 **landmark trajectory**에 **least square error**를 최소화하는 **circle fitting** 및 **center of rotation 도출**



Least square error criterion:

$$\text{Min} \sum_{i=1}^N (R_i - R)^2$$

* Where $R_i = (x_i - A)^2 + (y_i - B)^2$
 (x_i, y_i) = Marker locations
 (A, B) = Calculated joint CoR
 R = Radius of the fitted circle over the trajectory of marker motion

KASA. (1976). A Circle Fitting Procedure and Its Error Analysis. IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, 8-14.

HTM 개발: Joint CoR 도출 및 Link Model 생성

Hand Joint CoR 추정 결과

Digits	Joint	Coordinates		
		X	Y	Z
Digit 2	Tip	-4.15	-6.1	-98.16
	DIP	-1.85	-9.36	-76.81
	PIP	0.45	-13.83	-52.38
	MCP	0.67	-29.17	-10.23
Digit 3	Tip	-23.77	-4.15	-105.64
	DIP	-22.06	-9.28	-82.88
	PIP	-20.78	-16.39	-55.17
	MCP	-19.68	-25.48	-6.63
Digit 4	Tip	-43.83	-4.55	-93.14
	DIP	-42.38	-8.59	-70.29
	PIP	-40.14	-12.9	-43.96
	MCP	-35.41	-18.21	0.8
Digit 5	Tip	-68.04	-2.59	-65.44
	DIP	-65.42	-6.25	-44.81
	PIP	-60.51	-10.26	-26.71
	MCP	-52.06	-12.32	8.34
Digit 1	Tip	31.47	-6.79	-41.49
	IP	31.65	-11.61	-16.29
	MCP	29.43	-12.17	17.01
	CMC	12.24	-16.7	48.18
Wrist		-20.47	-17.32	70.64

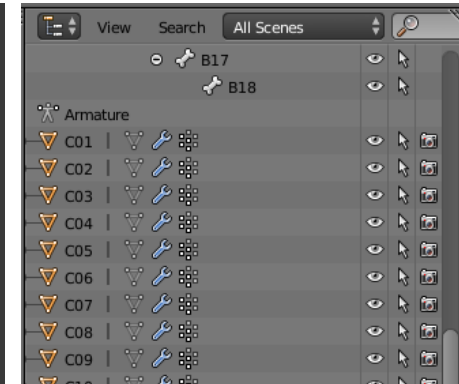
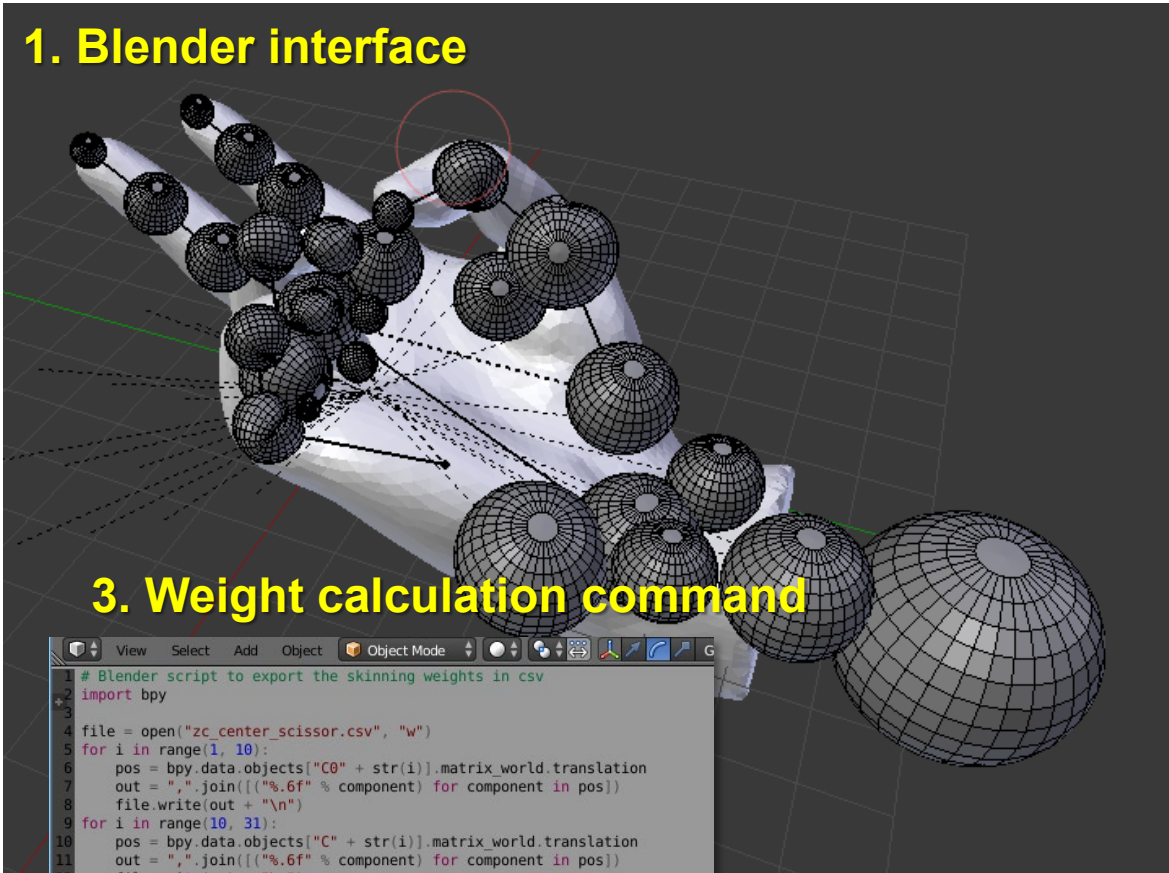
CoR 기반 hand link 생성 (digits 1~5)



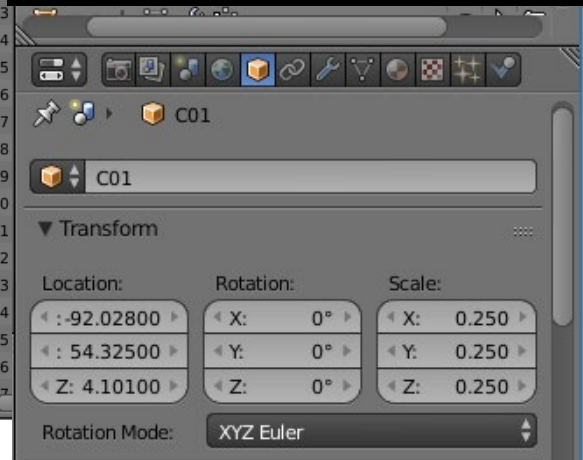
HTM 개발: Weight Calculation

- ❑ Hand joint center 위치에 따른 surface vertex의 weight (range: 0 ~ 1) 연산
- ❑ Blender를 이용하여 weight 연산 및 CSV format으로 출력 가능

1. Blender interface



2. CoR coordinate input



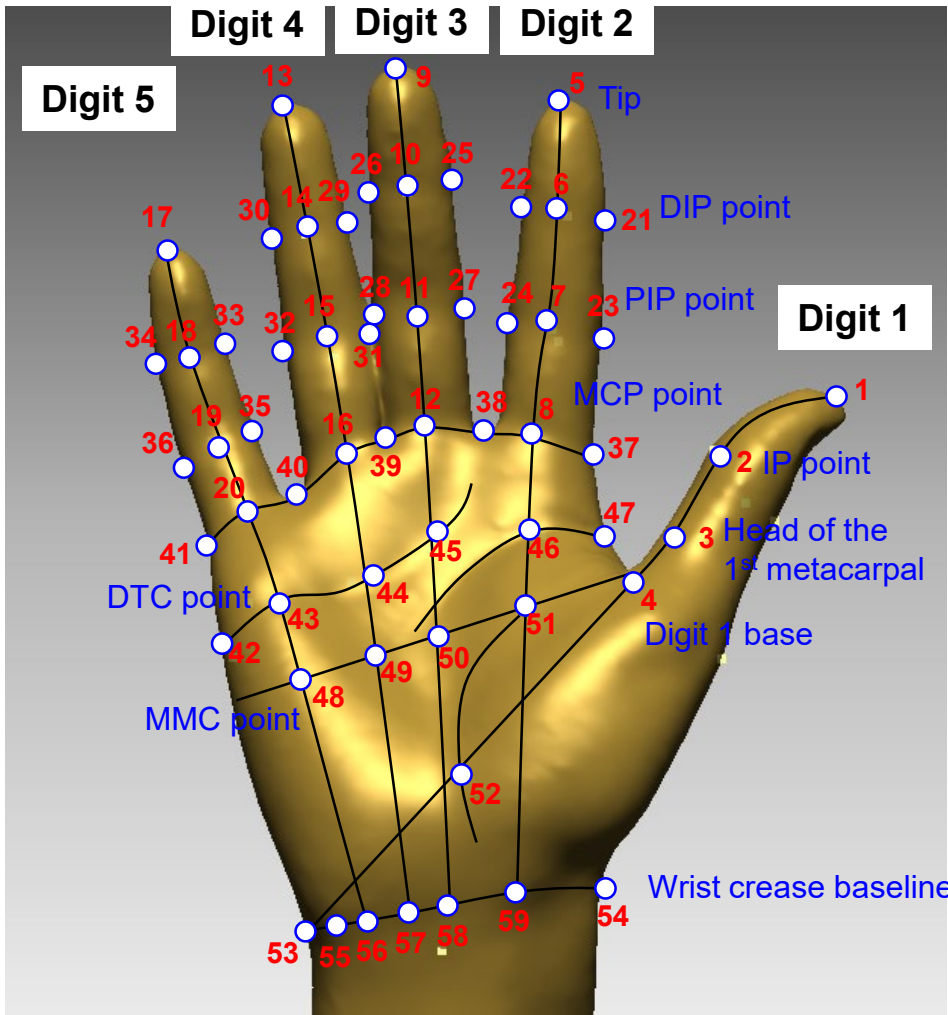
3. Weight calculation command

```
1 # Blender script to export the skinning weights in csv
2 import bpy
3
4 file = open("zc_center_scissor.csv", "w")
5 for i in range(1, 10):
6     pos = bpy.data.objects["C0" + str(i)].matrix_world.translation
7     out = ", ".join("%.6f" % component for component in pos)
8     file.write(out + "\n")
9 for i in range(10, 31):
10    pos = bpy.data.objects["C" + str(i)].matrix_world.translation
11    out = ", ".join("%.6f" % component for component in pos)
12    file.write(out + "\n")
13
14 file.close()
```


HTM 개발: Hand Landmark (1/3)

손 치수 측정에 활용되는 손등/손바닥 부위의 주요 landmark 75개 선정

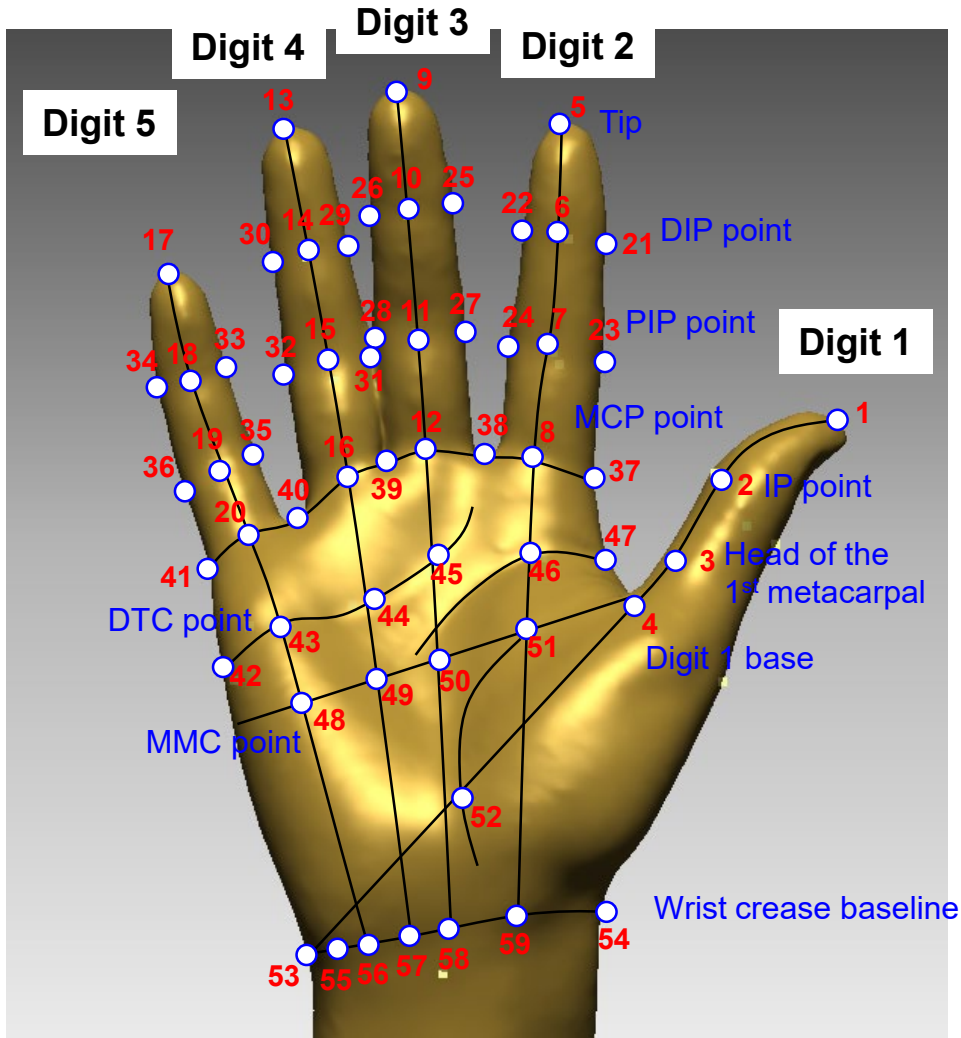
75개 hand landmark



No.	Name	No.	Name
1	The tip of digit 1	21	Digit 2 distal interphalangeal joint - radial
2	Digit 1 interphalangeal joint	22	Digit 2 distal interphalangeal joint - ulnar
3	Head of the first metacarpal	23	Digit 2 proximal interphalangeal joint - radial
4	The base of digit 1	24	Digit 2 proximal interphalangeal joint - ulnar
5	The tip of digit 2	25	Digit 3 distal interphalangeal joint - radial
6	Digit 2 mid-point of third crease	26	Digit 3 distal interphalangeal joint - ulnar
7	Digit 2 mid-point of second crease	27	Digit 3 proximal interphalangeal joint - radial
8	Digit 2 mid-point of first crease	28	Digit 3 proximal interphalangeal joint - ulnar
9	The tip of digit 3	29	Digit 4 distal interphalangeal joint - radial
10	Digit 3 mid-point of third crease	30	Digit 4 distal interphalangeal joint - ulnar
11	Digit 3 mid-point of second crease	31	Digit 4 proximal interphalangeal joint - radial
12	Digit 3 mid-point of first crease	32	Digit 4 proximal interphalangeal joint - ulnar
13	The tip of digit 4	33	Digit 5 distal interphalangeal joint - radial
14	Digit 4 mid-point of third crease	34	Digit 5 distal interphalangeal joint - ulnar
15	Digit 4 mid-point of second crease	35	Digit 5 proximal interphalangeal joint - radial
16	Digit 4 mid-point of first crease	36	Digit 5 proximal interphalangeal joint - ulnar
17	The tip of digit 5	37	Palm breadth - radial edge
18	Digit 5 mid-point of third crease	38	Crotch 2
19	Digit 5 mid-point of second crease	39	Crotch 3
20	Digit 5 mid-point of first crease	40	Crotch 4

HTM 개발: Hand Landmark (2/3)

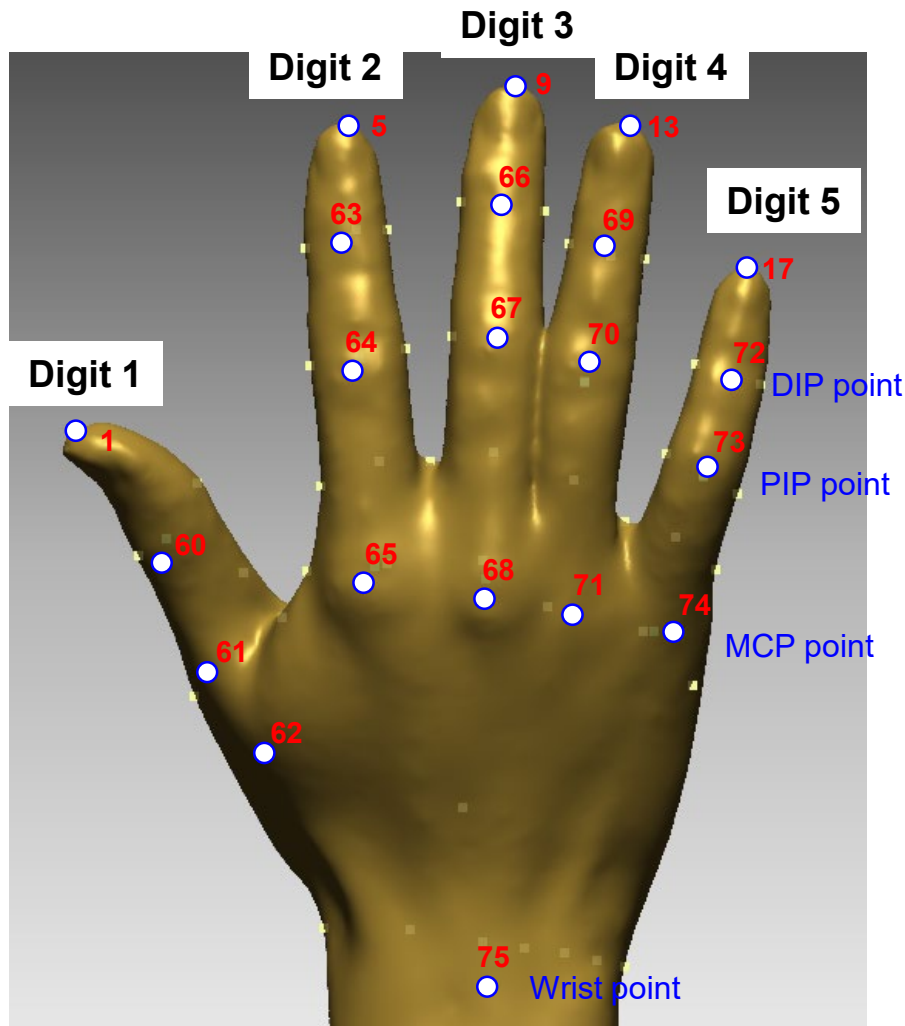
손바닥 부위의 주요 landmark 59개 선정



No.	Name
41	Palm breadth – ulnar edge
42	Proximal transverse palm crease - ulnar
43	Digit 2 distal transverse crease (DTC)
44	Digit 3 distal transverse crease (DTC)
45	Digit 4 distal transverse crease (DTC)
46	Digit 5 proximal transverse crease (PTC)
47	Proximal transverse palm crease - radial
48	Digit 2 mid-metacarpal (MMC)
49	Digit 3 mid-metacarpal (MMC)
50	Digit 4 mid-metacarpal (MMC)
51	Digit 5 mid-metacarpal (MMC)
52	Base of the first metacarpal
53	Ulnar edge of the distal wrist crease
54	Radial edge of the distal wrist crease
55	Digit 1 distal wrist crease
56	Digit 5 distal wrist crease
57	Digit 4 distal wrist crease
58	Digit 3 distal wrist crease
59	Digit 2 distal wrist crease

HTM 개발: Hand Landmark (3/3)

손등 부위의 주요 landmark 16개 선정

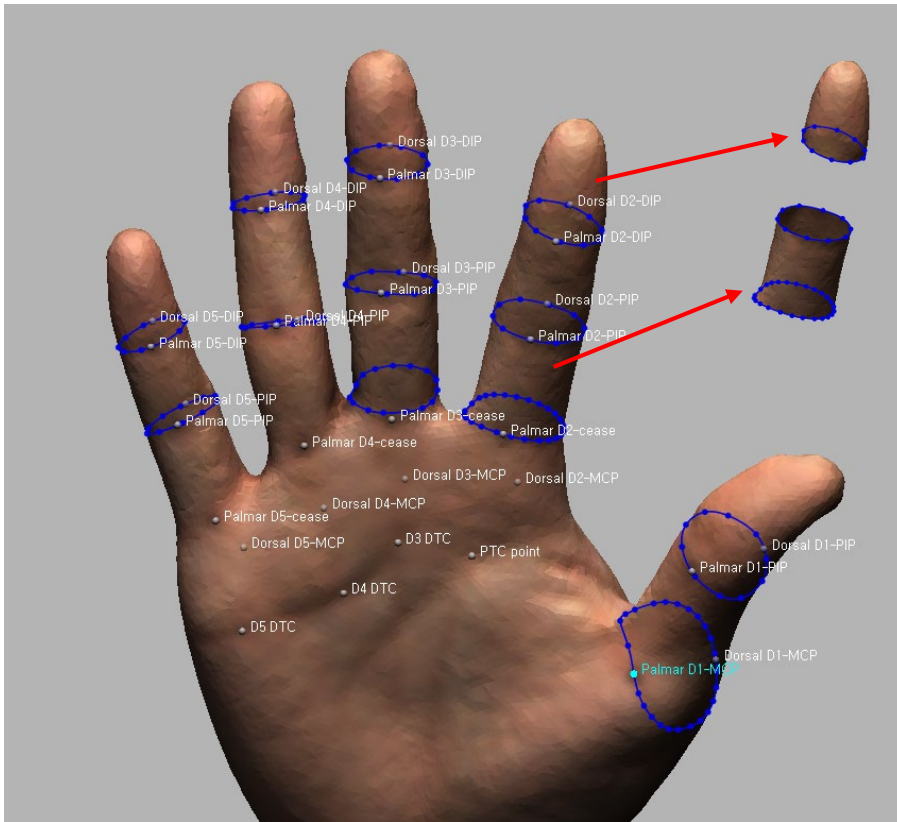


No.	Name
60	Digit 1 distal phalangeal joint - dorsal
61	Digit 1 proximal phalangeal joint – dorsal
62	Digit 1 metacarpal joint - dorsal
63	Digit 2 distal phalangeal joint – dorsal
64	Digit 2 proximal phalangeal joint – dorsal
65	Digit 2 metacarpal joint – dorsal
66	Digit 3 distal phalangeal joint – dorsal
67	Digit 3 proximal phalangeal joint – dorsal
68	Digit 3 metacarpal joint – dorsal
69	Digit 4 distal phalangeal joint – dorsal
70	Digit 4 proximal phalangeal joint – dorsal
71	Digit 4 metacarpal joint – dorsal
72	Digit 5 distal phalangeal joint – dorsal
73	Digit 5 proximal phalangeal joint – dorsal
74	Digit 5 metacarpal joint – dorsal
75	Wrist (origin)

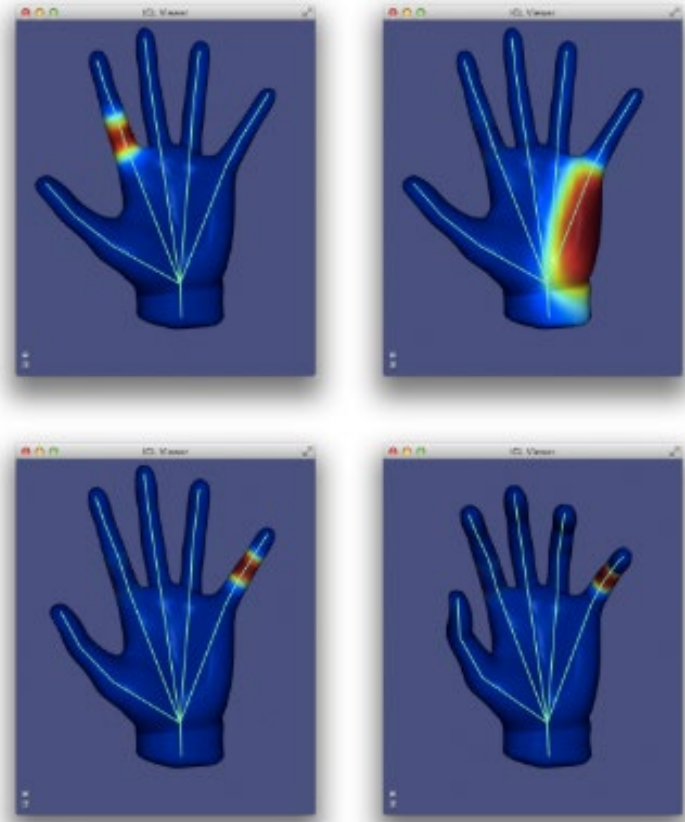
HTM 개발: Segmentation

Hand landmark를 기준으로 손가락 및 손 부위를 16가지 영역으로 mesh 분리

Hand mesh separation 예



Hand mesh separation 및 weight 적용 예

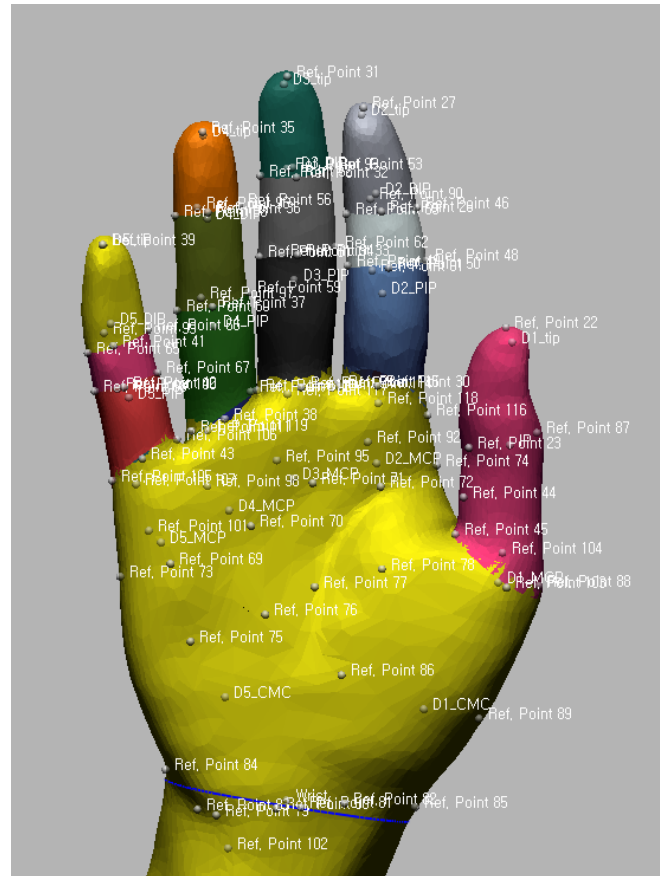


HTM 개발 결과

CoR estimation 결과

Digits	Joint	Coordinates		
		X	Y	Z
Digit 2	Tip	-4.15	-6.10	-98.16
	DIP	-1.85	-9.36	-76.81
	PIP	0.45	-13.83	-52.38
	MCP	0.67	-29.17	-10.23
Digit 3	Tip	-23.77	-4.15	-105.64
	DIP	-22.06	-9.28	-82.88
	PIP	-20.78	-16.39	-55.17
	MCP	-19.68	-25.48	-6.63
Digit 4	Tip	-43.83	-4.55	-93.14
	DIP	-42.38	-8.59	-70.29
	PIP	-40.14	-12.90	-43.96
	MCP	-35.41	-18.21	0.80
Digit 5	Tip	-68.04	-2.59	-65.44
	DIP	-65.42	-6.25	-44.81
	PIP	-60.51	-10.26	-26.71
	MCP	-52.06	-12.32	8.34
Digit 1	Tip	31.47	-6.79	-41.49
	IP	31.65	-11.61	-16.29
	MCP	29.43	-12.17	17.01
	CMC	12.24	-16.70	48.18
Wrist		-20.47	-17.32	70.64

Hand region segmentation

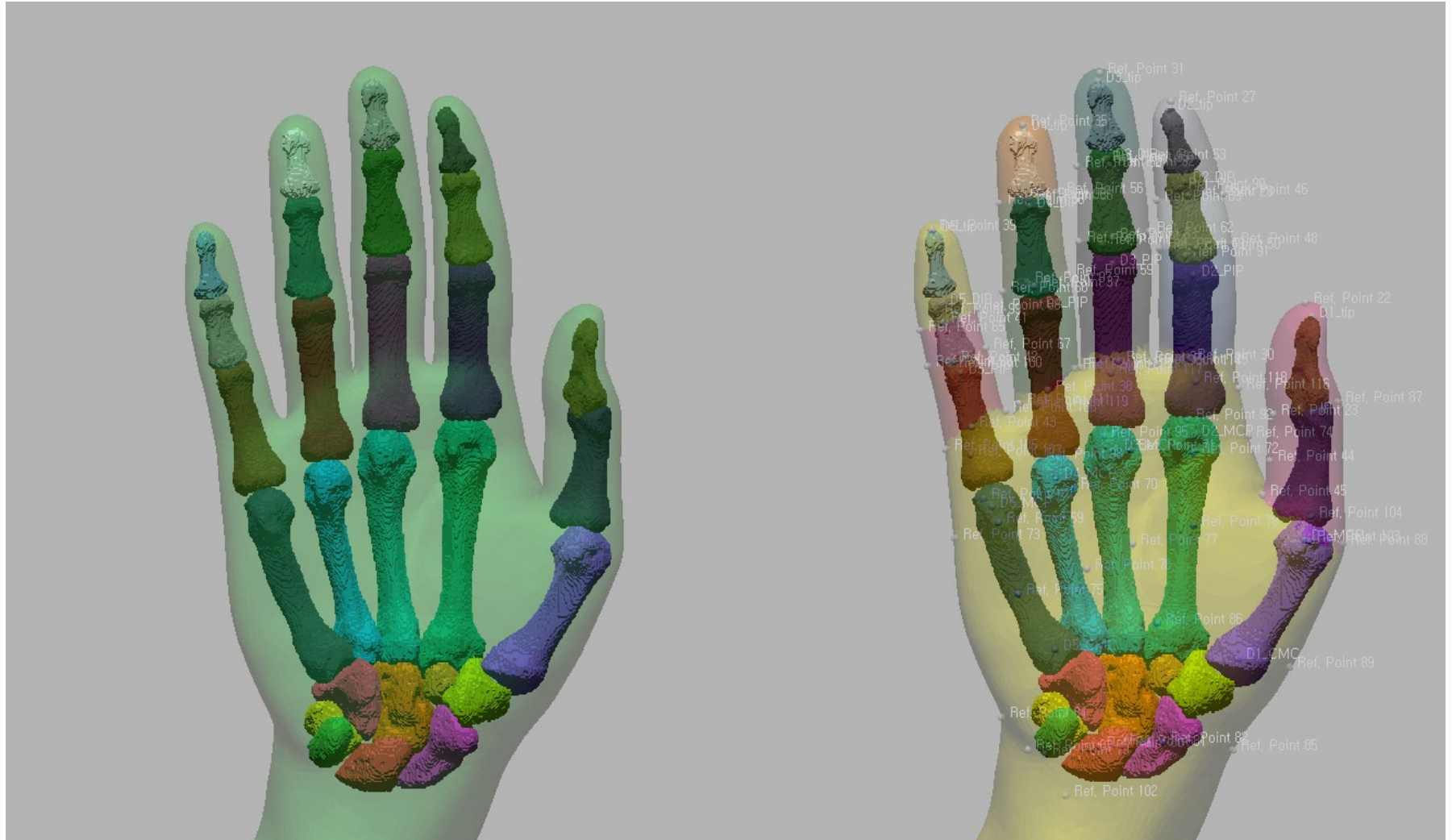


Hand bond & joint CoR



- Vertex: 19,755
- Face: 39,408

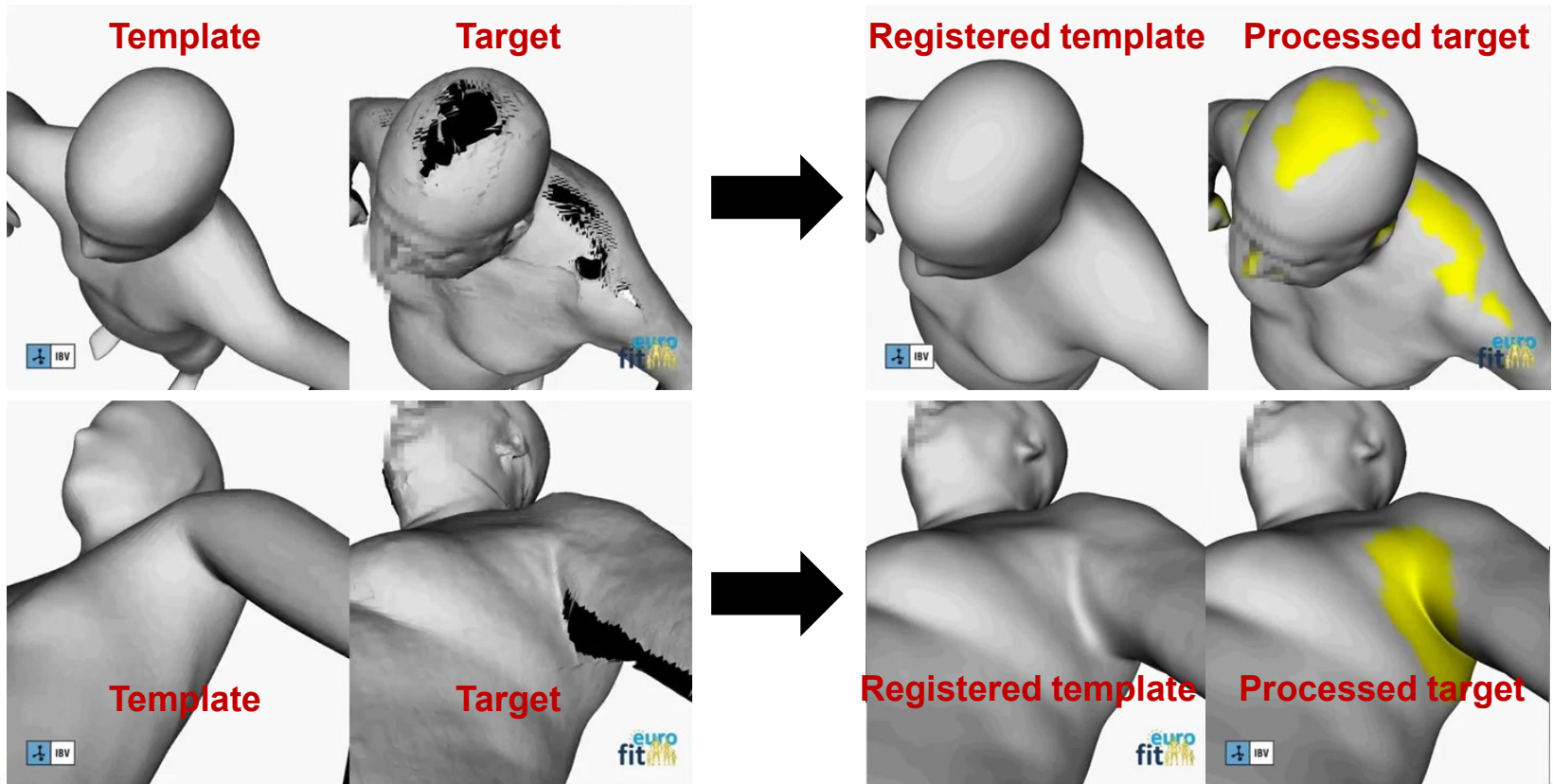
HTM 개발 결과



HTM Application: Template Registration (1/3)

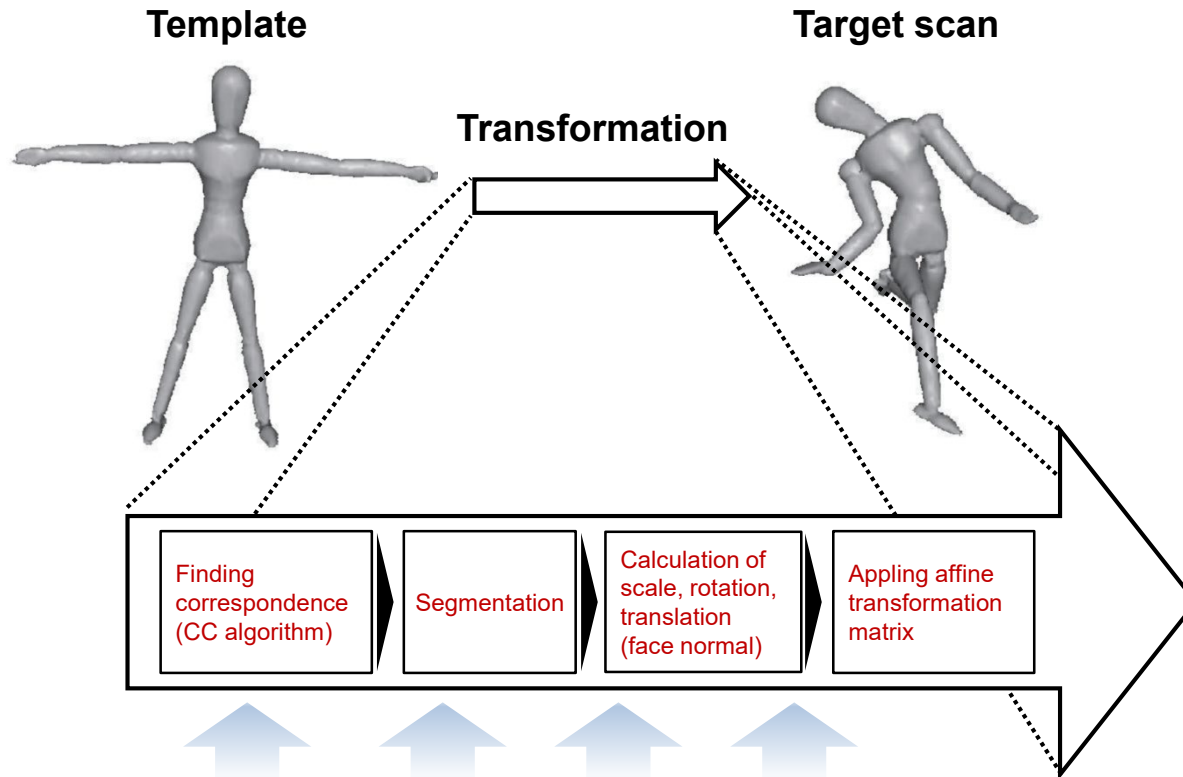
- 표준 자세(standing posture)로 측정된 3D body scan에 Template Model을 정렬
- Template registration 방법은 기존 3D scan 시 획득이 어려운 **접힘부 등의 missing part**에 대하여 기존 인체 **database**를 이용한 보강 시 유용함

Human Body Template Model을 이용한 형상 보강 예



HTM Application: Template Registration (2/3)

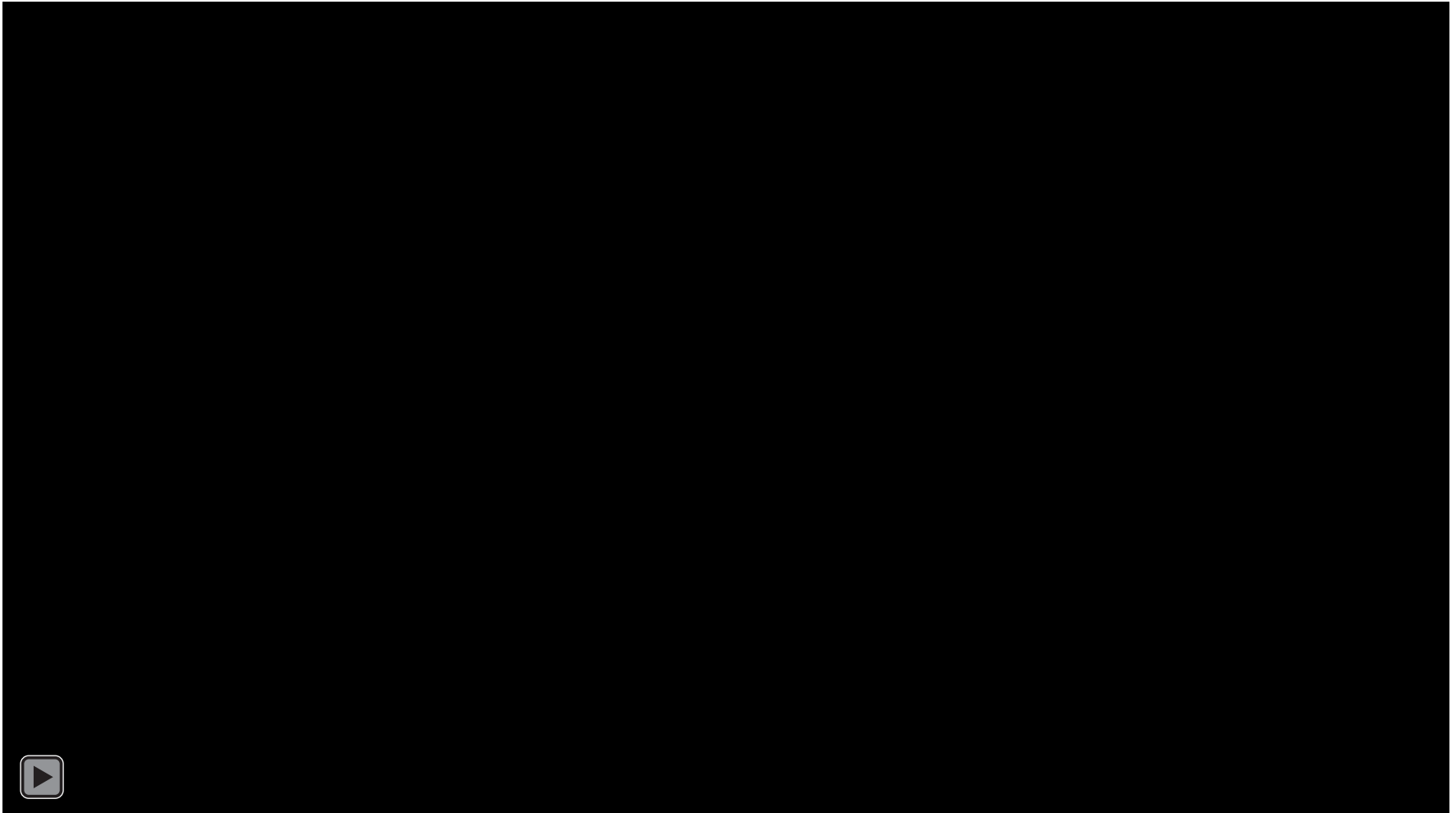
- ❑ Template의 vertex i 와 target scan의 vertex j 의 mapping 및 transform 문제
- ❑ Mapping 시 CC algorithm 적용, transform 시 affine transformation 적용



- **Data term** (vertex coordination)
- **Smoothness term** (similar affine transformation to vertex which belongs to the same face)
- **Landmark term** (distance among the landmarks of Template & Target scan)

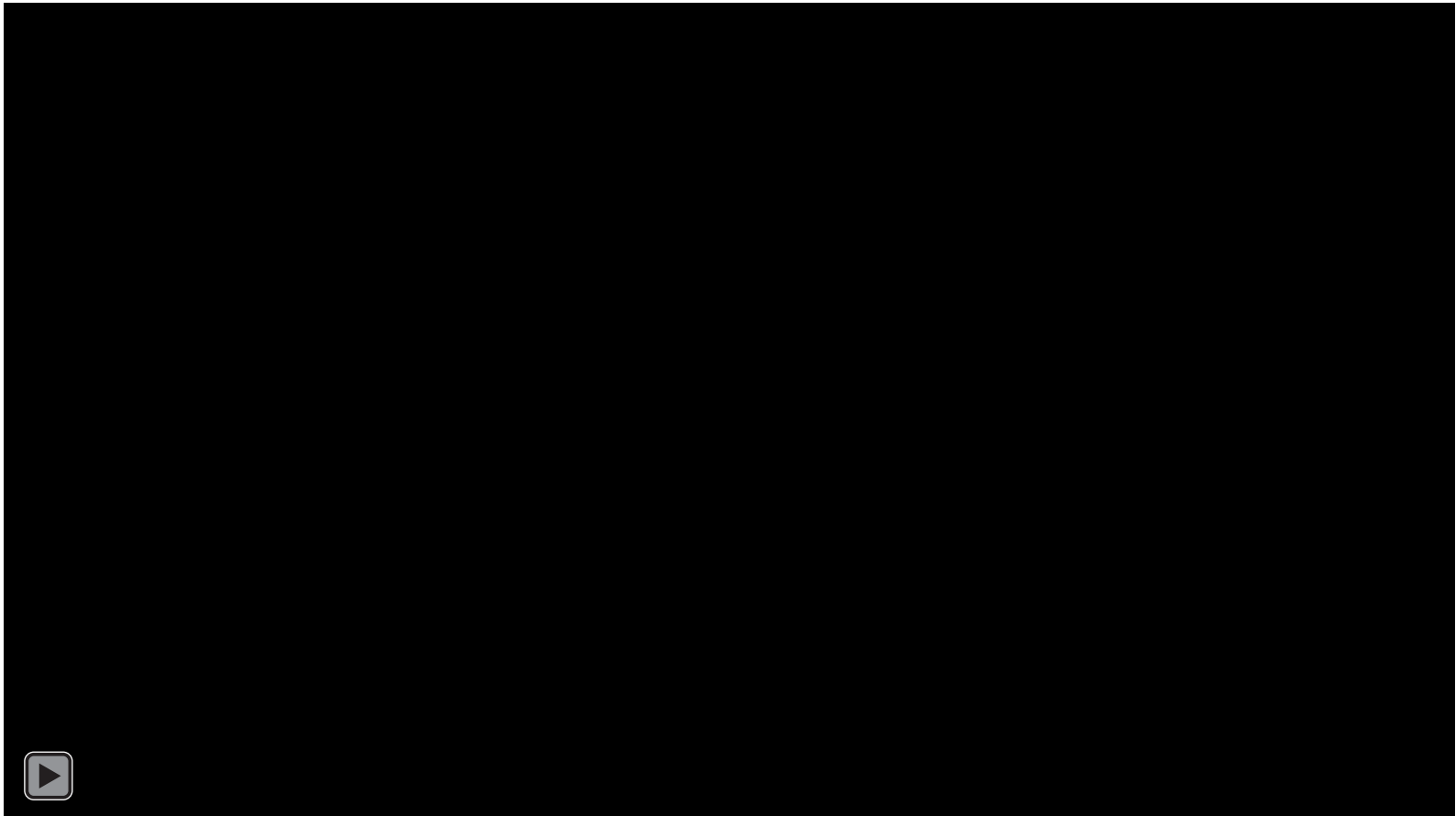
Template Registration (IBV, Spain): Video

Posing of Template \Rightarrow **Pre-processing** of Body Scan \Rightarrow **Fitting** of Template to Body Scan



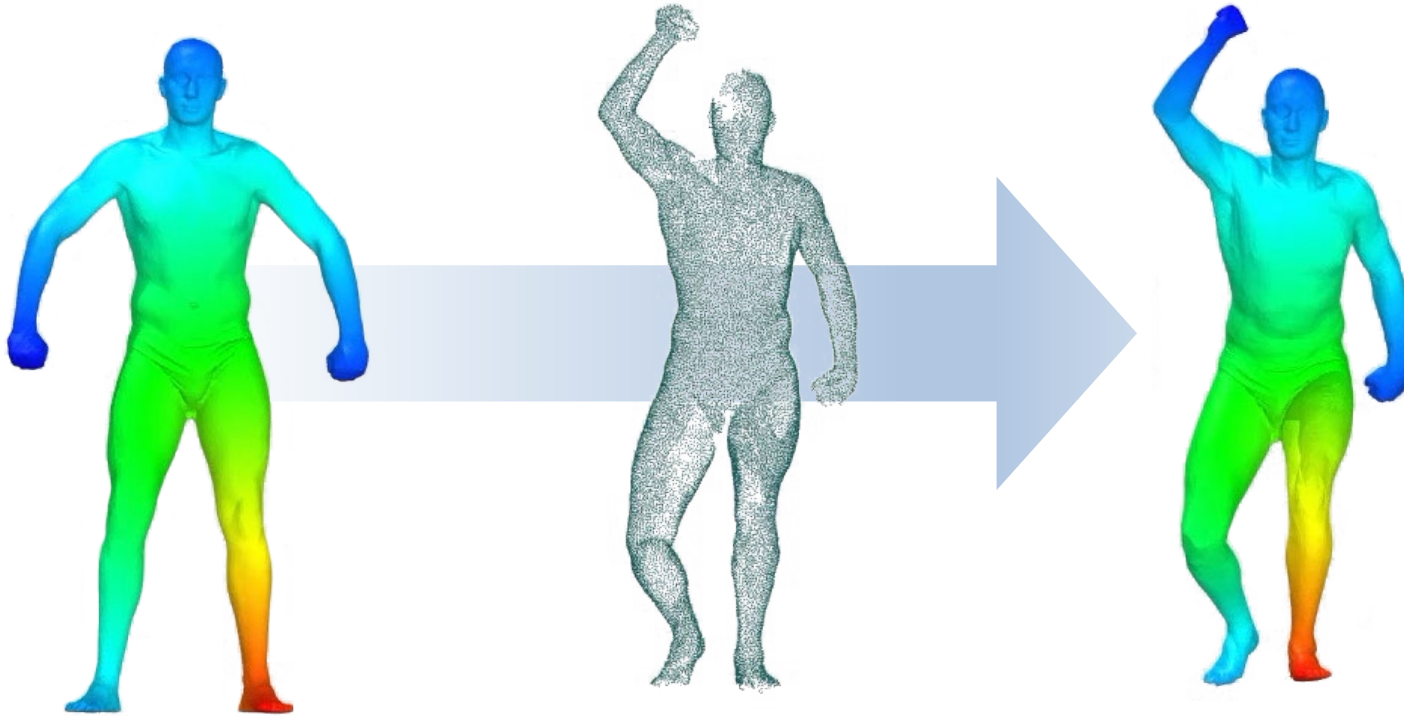
Template Registration (Hao Li): Video

- 최근에 개발되고 있는 기술은 **다른 자세**, **incomplete scan** data에도 높은 성능의 registration 성능을 보임



HTM Application: Posture Control

- 3D scan 기준 자세(standing, neutral)로 측정된 기존 3차원 인체형상 데이터를 **다양한 자세로 자세 변경 가능**
- 특정 자세(e.g., 제품 사용 자세 등)로의 변형 후 인체 계측 등에 **활용 가능**



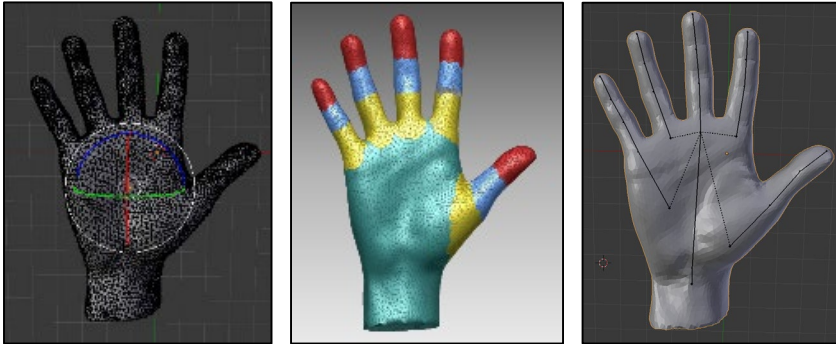
기준 자세 scan data
(CAESAR data, Size Korea 3D data)

특정 자세 측정 scan data

특정 자세로 3d data 변환

HTM Application: Posture Control 적용 예 (Implicit Skinning)

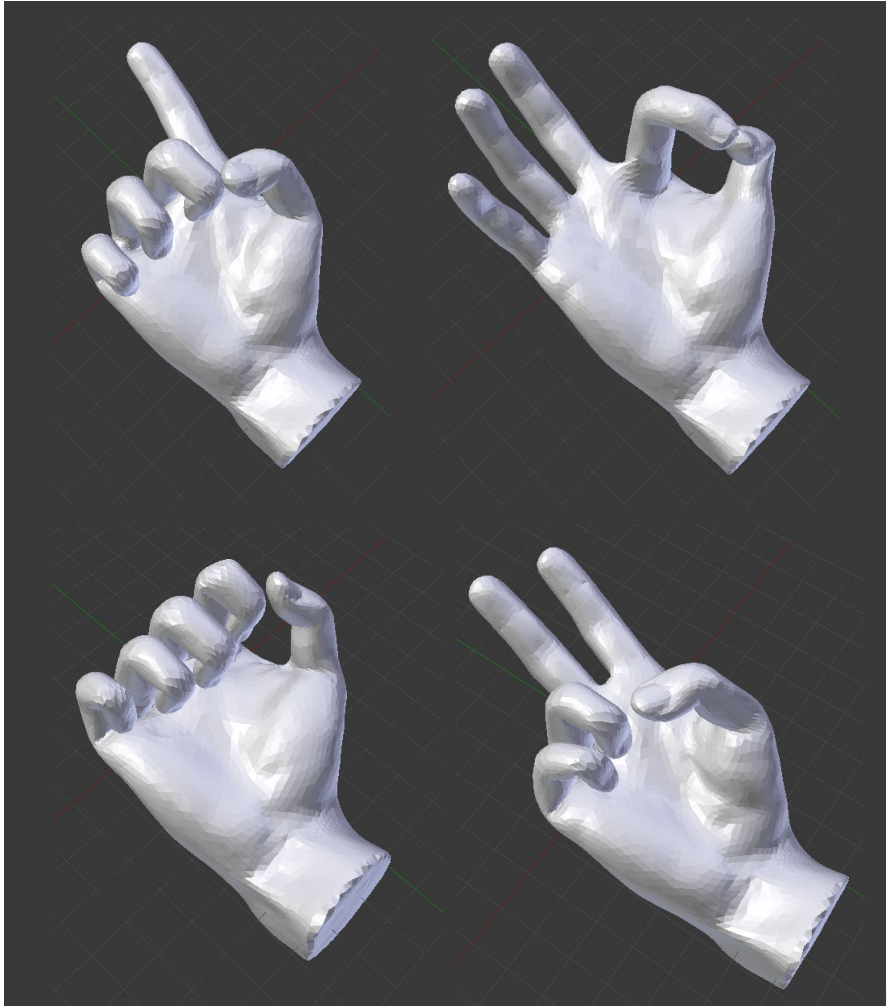
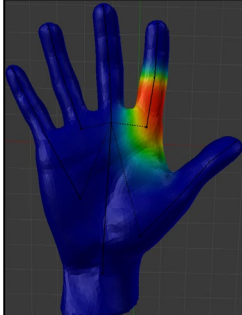
- 중립 자세의 hand template에 **implicit skinning** 방법을 적용하여 자연스러운 변형이 적용된 손 자세 도출



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13	B14	B15	B16	B17	B18	
2	0	0	0	0.10843	0.890894	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0.084782	0.914681	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0.196993	0.801702	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0.722384	0.269977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0.057907	0.731907	0.176847	0	0.008072	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0.211347	0.787342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0.823375	0.165023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0.880217	0.070066	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.826396	0	0	0	0.095995	0	0	0.016578	0	0	0	0	0	0	0	0	0	0	0
11	0.8864012	0	0	0	0.032736	0	0	0.016931	0	0	0.019149	0	0	0	0	0	0	0	0
12	0.841049	0	0	0	0	0	0	0	0	0.033861	0	0.009145	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0.40074	0.594672	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0.807075	0.179067	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0.887548	0.107986	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0.807793	0.186725	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0.618889	0.378106	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0.146477	0.852736	0	0	0	0	0	0	0	0	0
19	0.500819	0	0	0	0.339226	0	0.142091	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0.105464	0.878444	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0.95064	0.041161	0	0	0	0	0	0	0	0
22	0.009079	0	0	0	0	0	0	0	0	0.894658	0	0.039807	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0.321645	0.673262	0	0	0	0	0	0	0	0	0

```

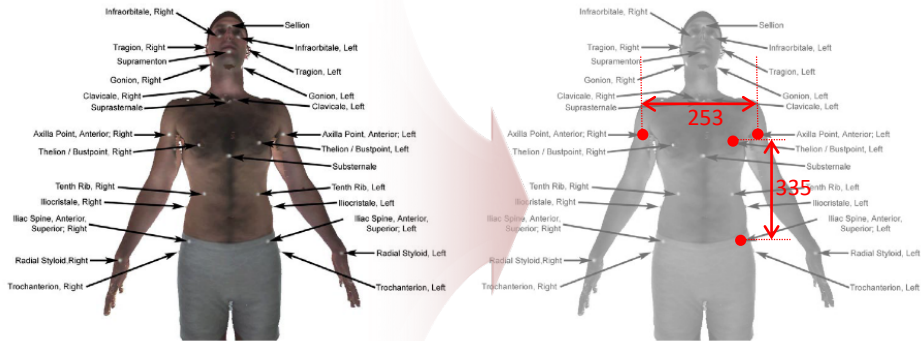
1 # Blender script to export the skinning weights in csv
2 import bpy
3
4 vertices = bpy.data.objects["hand"].data.vertices
5 group_names = [g.name for g in bpy.data.objects["hand"].vertex_groups]
6 bones_count = len(group_names)
7
8 file = open("zc_weights_1.csv", "w")
9 str = "", ".join([name for name in group_names])
10 file.write(str + "\n")
11
12 for v in vertices:
13     weights = [0 for i in range(bones_count)]
14     for g in v.groups:
15         weights[g.group] = g.weight
16     #str1 = "", ".join(["%.6f" % co for co in v.co])
17     str2 = "", ".join(["%.6f" % w for w in weights])
18     file.write(str2 + "\n")
19 file.close()
    
```



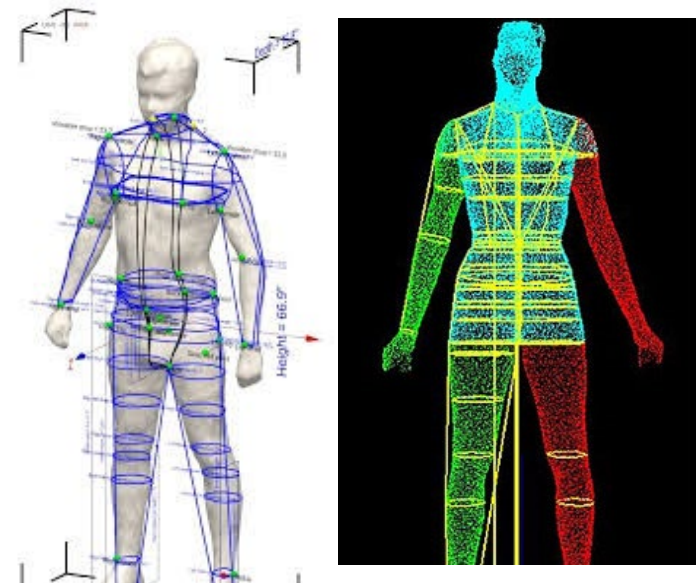
HTM Application: Automatic Anthropometry

- HTM 상에 기존에 정의된 landmark에 의하여 인체 부위의 형상(e.g., 곡률, 면적 등) 및 치수(e.g., 길이, 각도, 둘레길이 등) 측정
- Template matching 시 template model 상의 landmark, joint CoR, skeleton의 위치도 함께 정렬되어 변형된 HBTM 상의 landmark를 활용하여 자동으로 치수, 형상 및 자세 분석

Template Model을 이용한 인체 치수 측정



3차원 scan data의 landmark 자동 추출 기술



HTM Application: Pressure Estimation

- 제품 사용 및 파지 자세로 변형된 HTM과 제품간의 접촉 부위의 물성을 고려한 **손-제품 간 변형 특성 분석** 필요
- **제품의 물성 data** 및 **손 부위 물성 data library** 수집 및 **유한 요소 손 모델(finite element human hand model)** 개발 예정

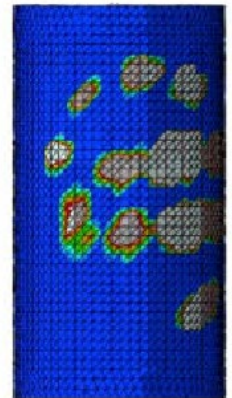
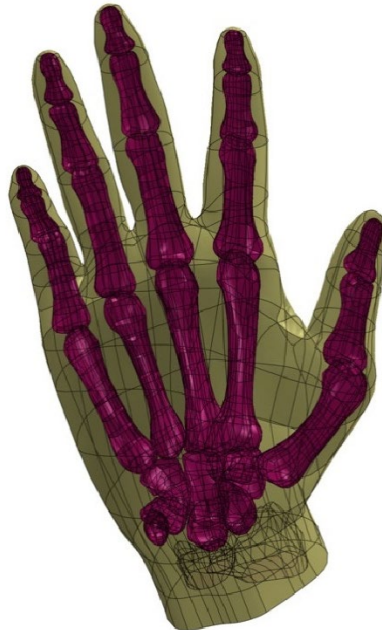
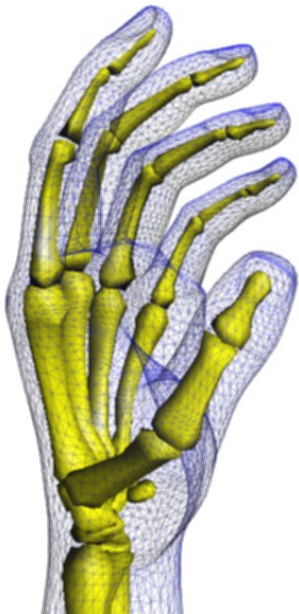
유한 요소 인체 모델(Hand Model) 개발 예시

Pressure estimation 예시

James et al. (2012)

Harih and Tada (2016)

Harih et al. (2017)



HTM Application: Product Design

- **Template model의 치수 및 형상 정보를 제품 설계 인자(design dimension)와 연동하면** 사용자의 인체 크기 및 형상에 따른 **맞춤형 제품 형상 설계 시 효율적으로 활용 가능함**

인체 형상 기반 맞춤형 제품 설계 절차 및 적용 예

(1) 제품 설계 주요 변수(variable) 정의



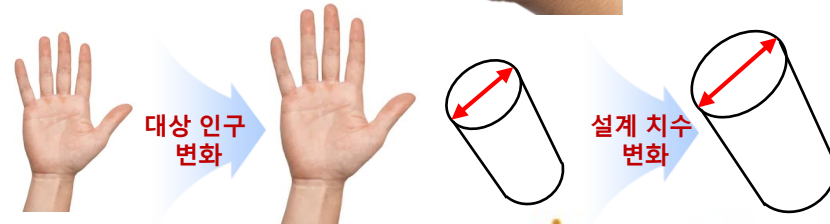
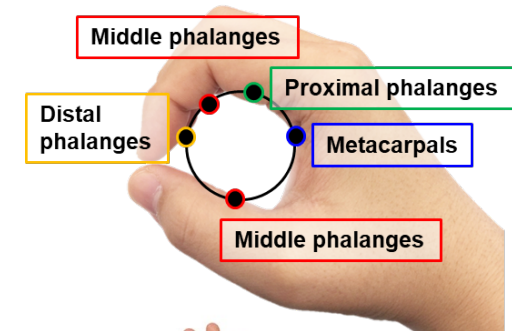
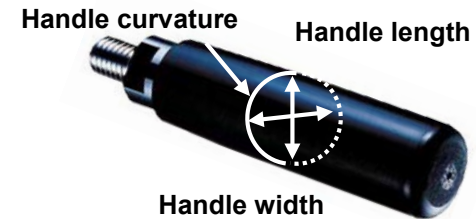
(2) Template model의 인체 변수(variable) 정의



(3) 제품설계변수-인체변수간 연동



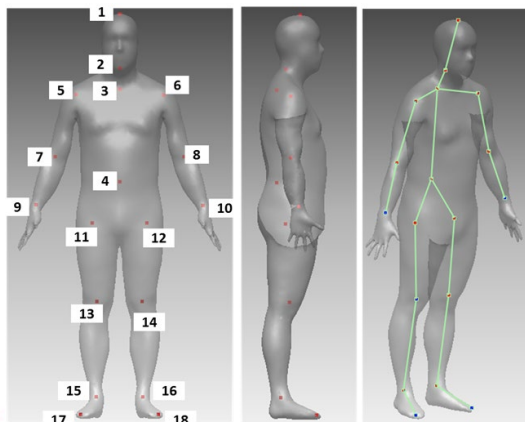
(4) 맞춤형 자동 설계 치수 제공



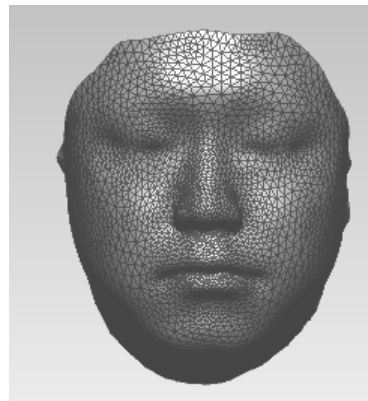
Discussion (1/3)

- 본 연구는 문헌 조사를 통하여 **Human Body & Hand Template Model**을 조사하고 **활용성을 파악함**
 - 인체 치수 및 형상의 자동 측정 가능함
 - 다양한 자세로 변형 가능
 - 인체-제품 간 상호작용 시 변형 특성 예측 가능
- **인체 부위별** 특성을 고려한 **Human Body & Hand Template Model**을 개발하면 제품 설계 시 효율적으로 활용 가능함
 - Whole body template 외 face template, hand template 개발

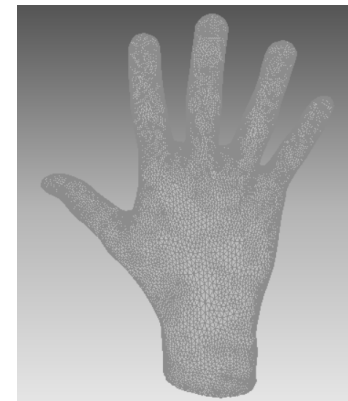
Whole body template



Face template



Hand template



Discussion (2/3)

- **Hand template model** 및 **인체형상 기술**은 개인 맞춤화를 필수적으로 요구하는 **dynamic scan data 기반 wearable handle 제품 설계** 시 적극적으로 활용 가능
 - 재활 치료 및 의수 제작
 - Exoskeleton 및 hand robot interface
 - 전투기 joystick과 같은 복잡한 형태의 customized handle 제품 설계

의수 제작 예



Exoskeleton 개발 예



Customized handle design 예

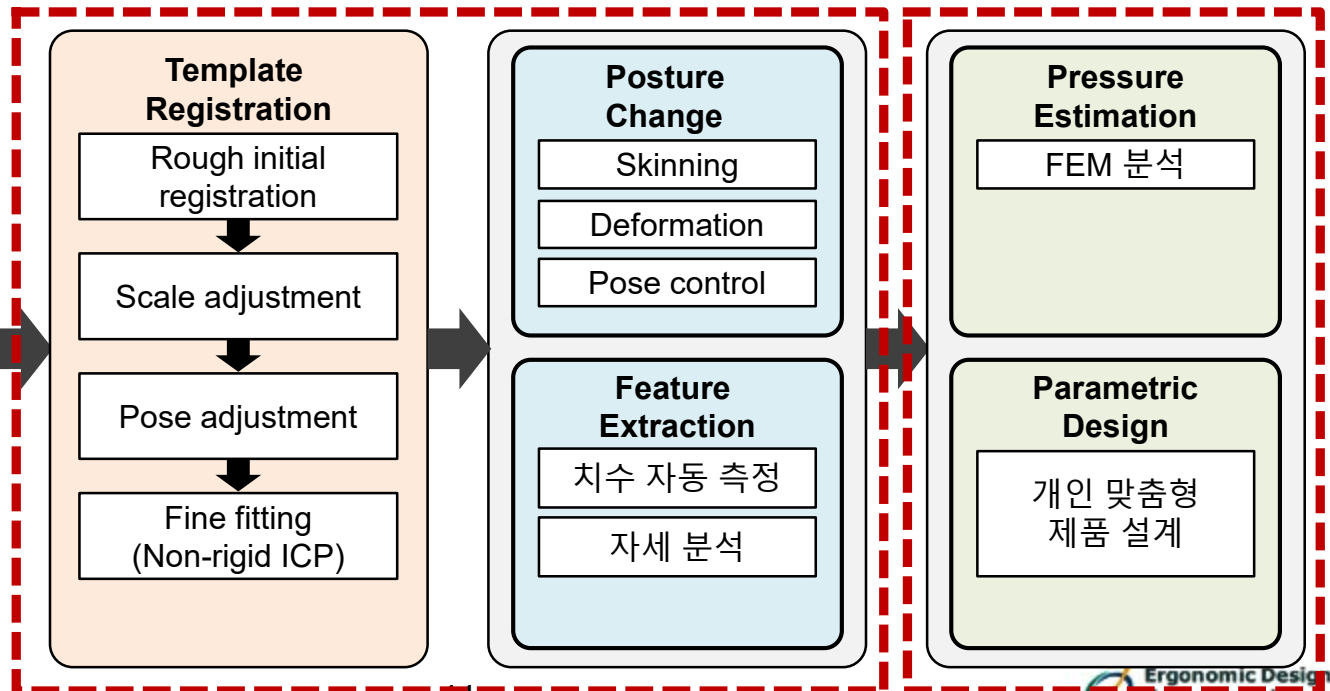
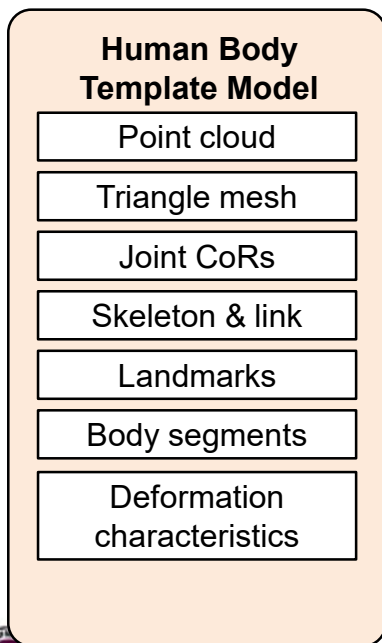


Discussion (3/3)

- 개발된 deformable human body template model을 기반으로 **3D registration 기술, 자세 변형 기술을 적용하여 다양한 제품 사용자세에서의 인체 형상 획득 및 분석** 예정
- Virtual fitting, FEM 분석 기술 및 parametric design 기술을 적용하여 개인 **인체 특성이 반영된 최적 제품 형상 설계 방법론 구축**

Phase 2: 인체 형상 분석 기술 개발

Phase 3: 최적 설계



Q & A



경청해 주셔서 감사합니다. ☺

본 연구는 한국연구재단의 중견연구자 지원사업(NRF-2018R1A2A2A05023299)의 지원을 받아 수행되었습니다.

edt.postech.ac.kr
niceterran36@postech.ac.kr

Template Registration 논문 List

No.	Year	Author(s)	Title	Source / Institute	중요도
1	2017	Pishchulin et al.	Building statistical shape spaces for 3D human modeling	Pattern Recognition / MPII	상
2	2003	Allen et al.	The space of human body shapes - reconstruction and parameterization from range scans	ACM Transactions on Graphics / Washington University	상
3	2005	Angulove et al.	SCAPE: Shape Completion and Animation of People	ACM Transactions on Graphics / MPI - PS	상
4	2005	Allen	Learning body shape models from real-world data	Dissertation of Washington Univ. / MPI - PS	상
5	2014	Rodola et al.	Robust Region Detection via Consensus Segmentation of Deformable Shapes	Computer Graphics Forum / TU Munich	상
6	2011	Jacopson et al.	Bounded Biharmonic Weights for Real-Time Deformation	ACM Transactions on Graphics / ETH Zurich IGL	상
7	2008	Li et al.	Global Correspondence Optimization for Non-Rigid Registration of Depth Scans	Eurographics Symposium on Geometry Processing / Hao Li	상
8	2010	Myronenko and song	Point Set Registration: Coherent Point Drift	IEEE Transactions on Pattern Analysis and Machine Intelligence / OHSU	상
9	2017	Romero et al.	Embodied Hands: Modeling and Capturing Hands and Bodies Together	ACM Transactions on Graphic / MPI - PS	상
10	2005	Anguelov et al.	The Correlated Correspondence Algorithm for Unsupervised Registration of Nonrigid Surfaces	Advances in Neural Information Processing Systems	상
11	2004	Sumner and Popovic	Deformation Transfer for Triangle Meshes	ACM Transactions on Graphic	상
12	2014	Bonarrigo et al.	Deformable registration using patch-wise shape matching	Graphical Models / Hao Li	상

Hand Template Model (HTM) 개발

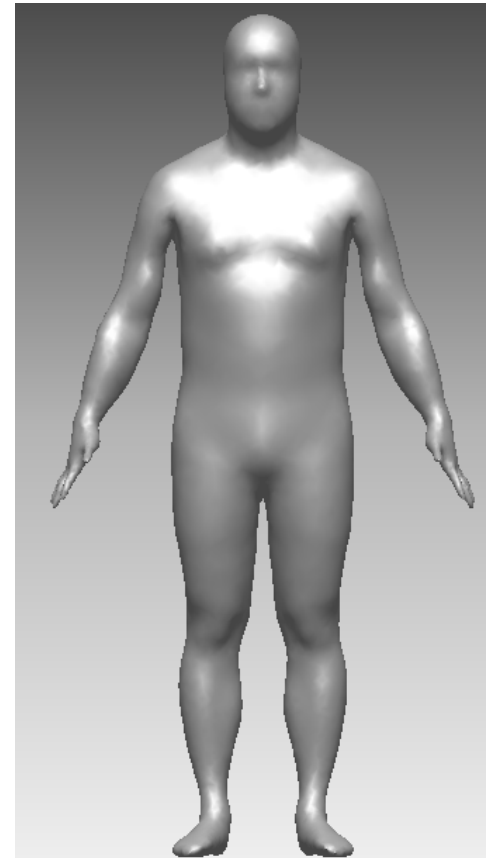
□ 평균 크기(50th%ile)의 3D human model을 가공하여 test template model 개발

Original image (CAESAR data)



- Hole filling
- Smoothing
- Symmetrizing

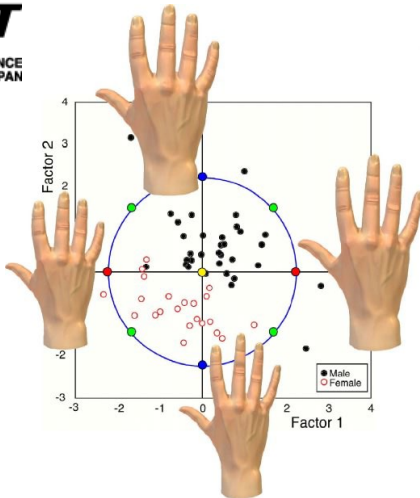
Template (test model)



State of the Art Hand Model: 검색 방법

- ❑ 검색 site: www.google.co.kr
- ❑ 검색 keyword: (“3D” or “digital”) and (“hand model”) and (“ergonomic”)
- ❑ 검색 결과: Dhaiba (Digital Human Aided Basic Assessment system) model (Kouchi, 2005)

Digital hand to assist design of products



Dhaiba model

SAE INTERNATIONAL

Learn > Publications > Technical Papers

Dhaiba: Functional Human Models to Represent Variation of Shape, Motion and Subjective Assessment Technical Paper

Paper #: 2006-01-2345 Published: 2006-07-04

DOI: 10.4271/2006-01-2345

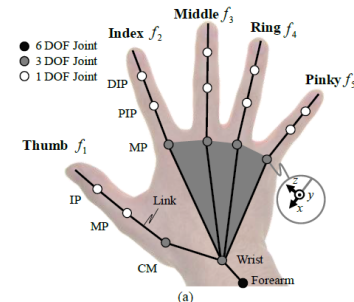
Citation: Mochimaru, M., Kouchi, H., Miyata, N., Tada, M. et al., "Dhaiba: Functional Human Models to Represent Variation of Shape, Motion and Subjective Assessment," SAE Technical Paper 2006-01-2345, 2006, doi:10.4271/2006-01-2345.

Author(s): Masaki Mochimaru, Masaki Kouchi, Tatsuki Miyata, Mitsunori Tada, Yoshiaki Itohara, Koji Kishi, Kazuaki Kuroki, Yoshihiro Morita

Affiliated: Digital Human Research Center, AIST (The National Institute of Advanced Industrial Science and Technology) CREST, JST (Japan Science and Technology Agency)

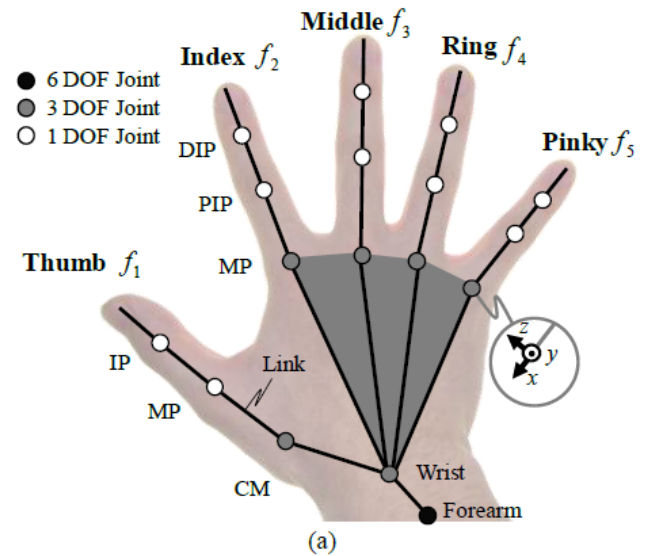
Buy	Select	List Price
Download	Download	\$26.00
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State of the Art Hand Model: Dhaiba Model (2006)

- ❑ Dhaiba is a **visualization software platform (VirTools®)** supports the design of human-compatible products
- ❑ Dhaiba integrates
 - **Human motions** with strategy differences
 - **Subjective assessment** of usability
- ❑ Dhaiba model can be implemented to **link structure model, surface skin model**



Further Researches Based on Dhaiba Model (Endo et al., 2007)

- ❑ Virtual Grasping Assessment Using 3D Digital Hand Model (Endo et al., 2007)
- ❑ Dhaiba Model based **grip analysis** (posture, grip point, hand shape, etc.) **system**

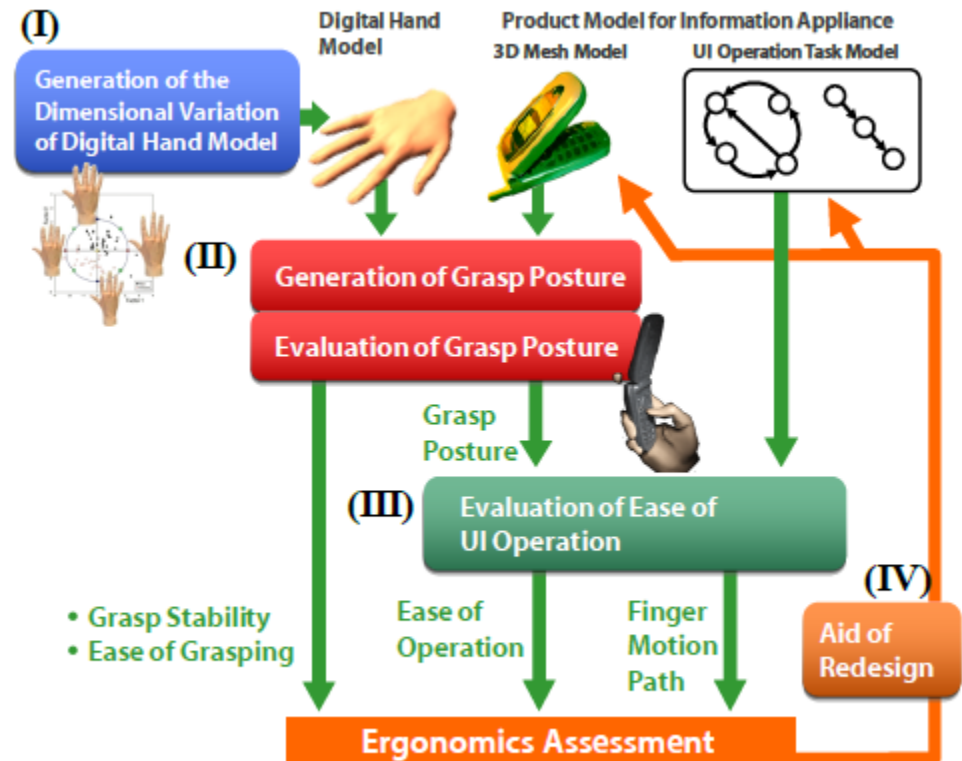
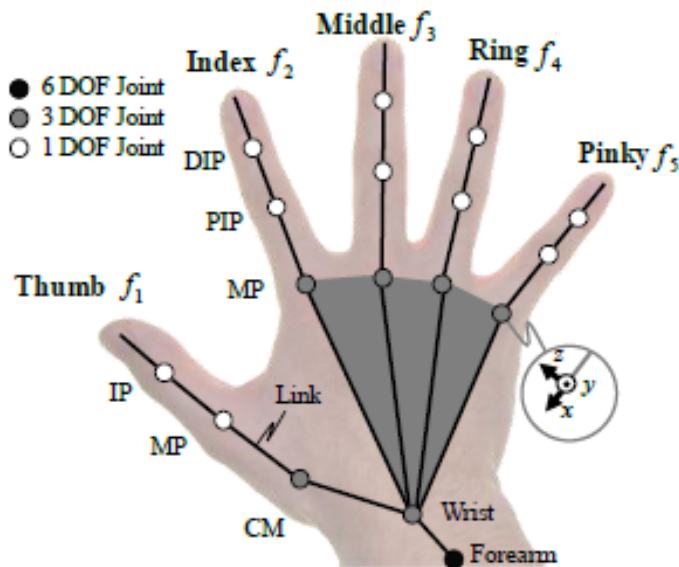


Figure 2. The overview of our proposed automatic ergonomic assessment system

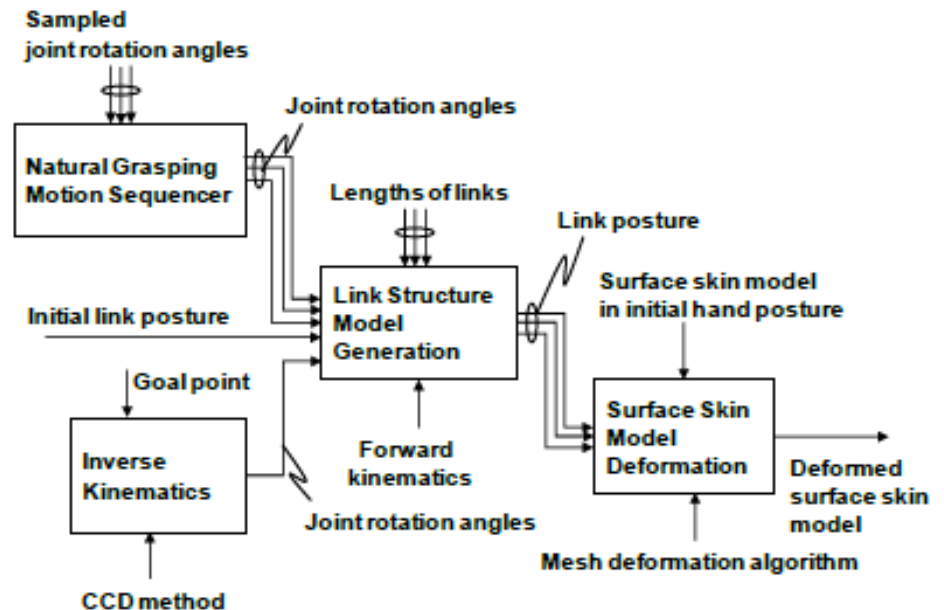
Further Researches Based on Dhaiba Model (Endo et al., 2007)

- ❑ Analyzing **natural grasping motion** using developed algorithm
- ❑ **Surface skin deformation, natural grasping motion part was added** to Dhaiba Model

Original Dhaiba Model



Developed Algorithm's Flow



Further Researches Based on Dhaiba Model (Endo et al., 2007)

□ Natural grasping procedures

- Input **initial information** and **goal points** to generate **precise hand grip** as parameters
- **Optimal hand grip posture** was generated to **maximize number of contact points**

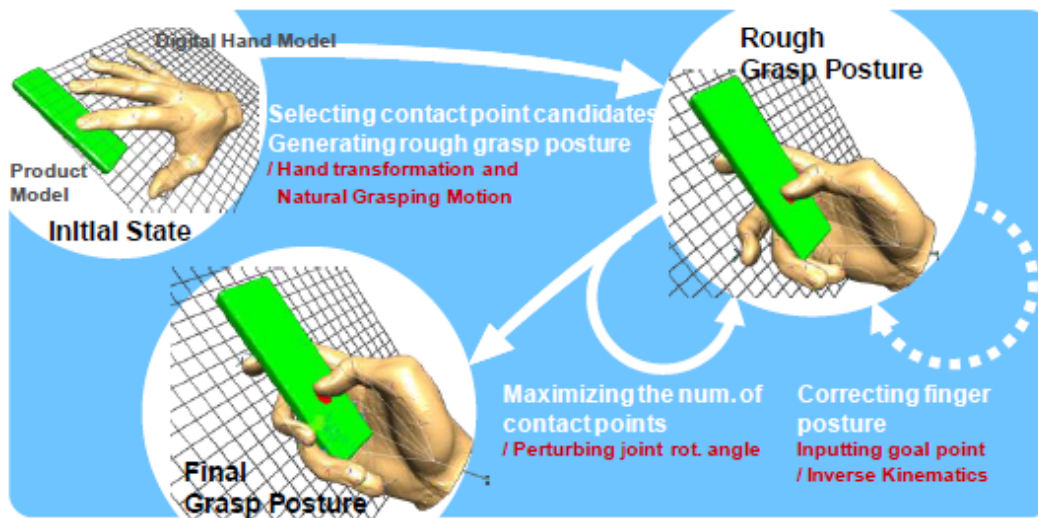


Figure 5. The algorithm to generate the grasp posture

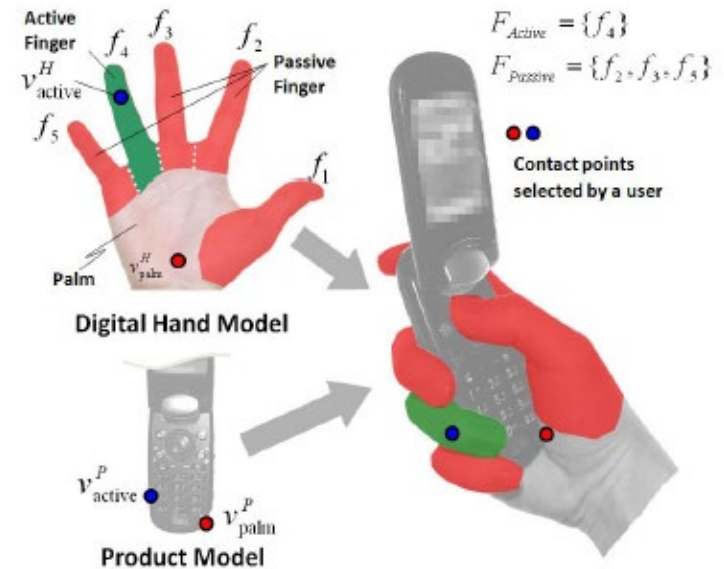


Figure 6. The selection of the contact point candidates

Recent Research: AIST

- ❑ Fast Grasp Planning for Hand/Arm Systems Based on Convex Model(Harada K. et al., 2008)
- ❑ Ananalysis of hand measurements for digital hand models (Kasai S. et al., 2003)
XVth Triennial Congress, International Ergonomics Association (IEA2003), 2003

2008 IEEE International Conference on
Robotics and Automation
Pasadena, CA, USA, May 19-23, 2008

Fast Grasp Planning for Hand/Arm Systems Based on Convex Model

Kensuke Harada, Kenji Kaneko, and Fumio Kanehiro

Abstract—This paper discusses the grasp planning of a multifingered hand attached at the tip of a robotic arm. By using the convex models and the new approximation method of the friction cone, our proposed algorithm can calculate the grasping motion within the reasonable time. For each grasping style used in this research, we define the *grasping rectangular convex (GRC)*. We also define the *object convex polygon (OCP)* for the grasped object. By considering the geometrical relationship among these convex models, we determine several parameters needed to define the final grasping configuration. To determine the contact point position satisfying the force closure, we use two approximation models of the friction cone. To save the calculation time, the rough approximation by using the ellipsoid is mainly used to check the force closure. Additionally, approximation by using the convex polyhedral cone is used at the final stage of the planning. The effectiveness of the proposed method is confirmed by some numerical examples.




Fig. 1. Humanoid HRP3P with multi-fingered hand

I. INTRODUCTION

A multi-fingered hand has the potential possibility to grasp several objects with different shape. However, the grasp planning of a multi-fingered hand often becomes difficult due to its complexity. In many cases, since a hand/arm system has more than 20 dof, we have to plan the grasping motion in the high-dimensional configuration space by using the following strategy: First, although there are plenty of possible grasping styles[18], we have to select a feasible one according to the required task. Then, we have to determine the contact point position on both the fingers and the grasped object. The contact point position has to be determined so that the finger can grasp the object without dropping it within the limit of the actuator power. Finally, we have to plan the motion of the hand/arm system from the initial configuration to the final one with avoiding unnecessary collision among the fingers and the environment.

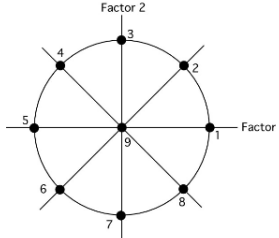
Now, let us consider some typical cases where the grasp planning is needed. The first example is the humanoid robot having a multi-fingered hand as shown in Fig.1. When a humanoid robot grasps an object, the humanoid robot will first measures the position/orientation of the object by using the vision sensor attached at the head. Then, based on this information, the grasp planner plans the motion of the hand/arm system to realize the final grasping posture. Once the planning finishes, the multi-fingered hand will pick up the object by grasping it. We can also consider the pick-and-place task in a manufacturing factory. In this case, several objects randomly placed on the belt conveyer will be delivered to the industrial robot manipulator. By measuring the position/orientation of the objects, the robot will plan the pick-and-place motion of the object. For both of the above cases, the grasping motion has to be calculated as fast as possible. Thus, as for the grasp planning, a heuristic but fast algorithm will be preferred rather than a precise but time-consuming algorithm[2].

In this paper, we propose a fast grasp planning algorithm for hand/arm systems. Our proposed algorithm can calculate the grasping motion within the reasonable time simultaneously satisfying several conditions for the grasp system such as the feasible grasping style, the friction cone constraint, the maximum contact force, the inverse kinematics of the arm and the fingers, and the collision among the fingers etc. The contribution of this paper is as follows; Our proposed algorithm first assumes the convex models for both the object and the grasping region of the hand. By considering the geometrical relationship between two models, we can determine several parameters needed to plan the grasp configuration. This is just like the problem of checking whether a block can be put into a box or not. Then, we determine the contact point position between the fingertip and the object. These points are determined so that the force closure can be satisfied. However, so as to reduce the calculation time, we propose two methods for testing the force closure. The first method is mainly used where it approximates the friction cone by using ellipsoid. This is a rough approximation but can quickly estimate the force closure. Additionally, we use more precise approximation by using the convex polyhedral cone. Furthermore, to determine the contact point position, we use the random sampling approach. The random sampling contributes to save the calculation time since we do not need to analytically obtain the region of the contact point

978-1-4244-1647-9/08/\$25.00 ©2008 IEEE. 1162

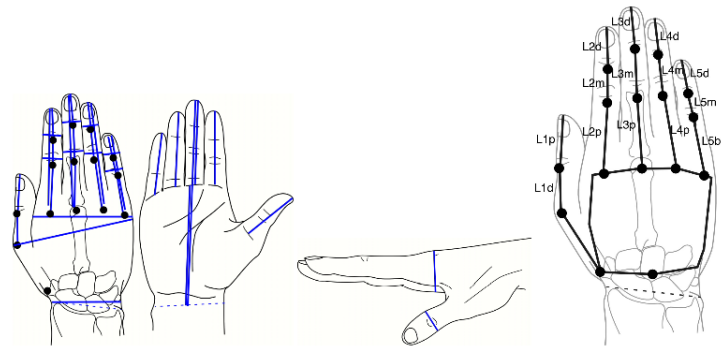
Boundary Family of Computer Manikins

This is a method to calculate body dimensions of representative forms for computer manikins by Bittner et al. (1986). Body dimensions are correlated with each other. By applying factor analysis, the information carried by the body dimensions is then summarized into 2 uncorrelated factors. By drawing a distribution map of subjects based on the obtained scores of the first 2 factors, a probability ellipsoid is defined in which 95% of the subjects will fall. The center of the distribution is the mean (#9). From the formula of the probability ellipsoid and the formulae of the X-axis (Y=0), the Y-axis (X=0), and Y=±X, we calculate the factor scores of the shapes which are at the intersecting points of the ellipsoid and the 2 factor axes (#1, #5, #3, #7), of the shapes at the intersecting points of the ellipsoid and Y=±X (#2, #4, #6, #8).



Shape Measurement of Hands

By using traditional methods, 25 dimensions were measured for 35 males and 22 females. On the assumption of a link structure, shown in the example drawing to the right, the dimensions to estimate the lengths of phalangeal joint links were measured. Factor analysis was conducted using a total of 39 measurement items.



Top Δ

Recent Research: AIST

□ AIST Reference site

- http://www.aist.go.jp/aist_e/aist_google_search_e.html?cx=004983608496508821980:avdsyoeo0bu&cof=FORID%3A10&ie=UTF-8&q=hand
- <http://www.dh.aist.go.jp/en/research/centered/dhand-link2/>
- <http://www.dh.aist.go.jp/en/research/centered/dhand-link1/>
- <https://unit.aist.go.jp/hiri/en/topics/06.html>
- <http://www.dh.aist.go.jp/en/research/centered/digitalhand/>

Literature 검색 방법: Research Group 검색

❑ Human body model, 3D scan technique 분야의 주요 research group을 파악하고 연구 관련 문헌 조사, 유관 문헌 수집 예정

❑ 주요 연구 group list

➤ Max Planck Institute for Perceiving Systems, Germany

➤ Advanced Industrial Science and Technology, Japan

➤ Max Planck Institute for Informatics, Germany

➤ Hao Li @ University of Southern California, USA

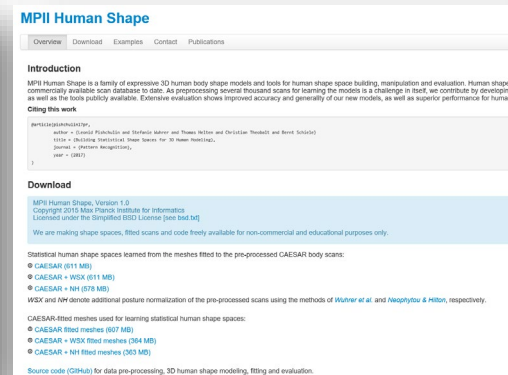
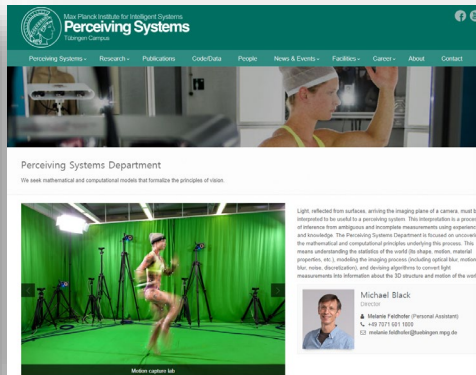
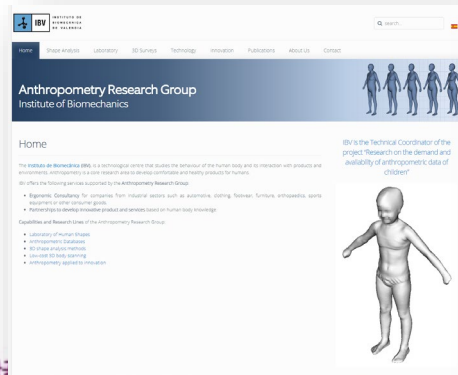
➤ Instituto de Biomechania de Valencia, Spain

➤ Interactive Geometry Lab, ETH, Switzerland

➤ Computer Vision Group, TU munchen, Germany

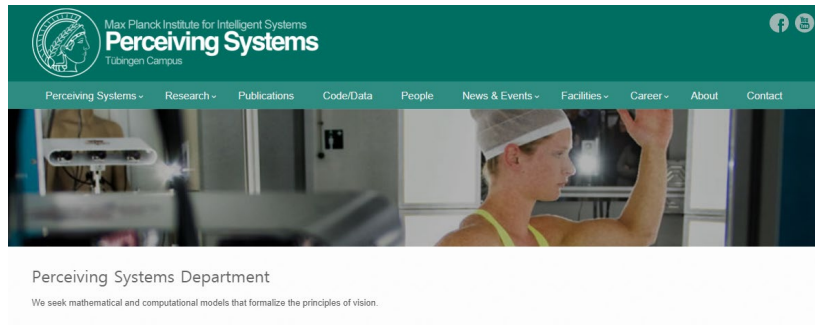
} Hand template benchmarking 대상

} 3D registration benchmarking 대상



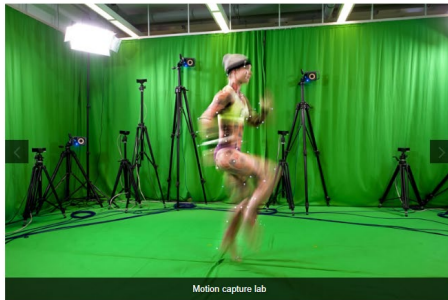
Perceiving Systems Lab (Max Planck Institute)

- ❑ Template model 기반 body shape, body deformation 형상 연구 선도 group
- ❑ Full body model 및 hand, foot 등 다양한 인체 부위 template 연구 수행 중
- ❑ Link: <https://ps.is.tuebingen.mpg.de/>



Perceiving Systems Department

We seek mathematical and computational models that formalize the principles of vision.



Motion capture lab

Light, reflected from surfaces, arriving the imaging plane of a camera, must be interpreted to be useful to a perceiving system. This interpretation is a process of inference from ambiguous and incomplete measurements using experience and knowledge. The Perceiving Systems Department is focused on uncovering the mathematical and computational principles underlying this process. This means understanding the statistics of the world (its shape, motion, material properties, etc.), modeling the imaging process (including optical blur, motion blur, noise, discretization), and devising algorithms to convert light measurements into information about the 3D structure and motion of the world.



Michael Black
Director
▲ Melanie Feldhofer (Personal Assistant)
☎ +49 7071 6011800
✉ melanie.feldhofer@tuebingen.mpg.de

- 📄 Ballester et al. (2014)
- 📄 Feix et al. (2016)
- 📄 Romero et al. (2017)
- 📄 Tzionas (2016)_Dissertation
- 📄 Tzionas and Gall (2015)
- 📄 Tzionas et al. (2013)
- 📄 Tzionas et al. (2014)
- 📄 Tzionas et al. (2016)



Embodied **Hand**s: Modeling and Capturing **Hand**s and Bodies Together [↗](#)
[Romero, J., Tzionas, D., Black, M. J.](#)

ACM Transactions on Graphics, (Proc. SIGGRAPH Asia), 36(6):245:1-245:17, 245:1-245:17, ACM, November 2017 (article)

Abstract [↕](#)

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- DOI
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Capturing **Hand**-Object Interaction and Reconstruction of Manipulated Objects [↗](#)
[Tzionas, D.](#)

University of Bonn, 2017 (phdthesis)

Abstract [↕](#)

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- 🔗 link (url)
- 📄 Project Page
- [BibTex]
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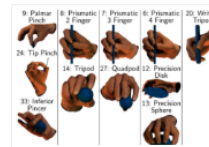


Capturing **Hands** in Action using Discriminative Salient Points and Physics Simulation [↗](#)
[Tzionas, D., Ballan, L., Srikantha, A., Aponte, P., Pollefeys, M., Gall, J.](#)

International Journal of Computer Vision (IJCV), 118(2):172-193, June 2016 (article)

Abstract [↕](#)

- 🌐 Website
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- DOI
- 📄 Project Page
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The GRASP Taxonomy of Human Grasp Types [↗](#)

Feix, T., [Romero, J.](#), Schriedmayer, H., Dollar, A., Kragic, D.

Human-Machine Systems, IEEE Transactions on, 46(1):66-77, 2016 (article)

- 🌐 publisher website
- 📄 pdf
- DOI
- [BibTex]
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AIST (Advanced Industrial Science and Technology)

- AIST Digital Human Research Group (DHRG)에서 hand template model 및 design 응용 연구 수행
- Link: <http://www.dh.aist.go.jp/en/>



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Message from the Director
Recruit

Message from the Director



Masaaki Mochimaru
Director
Digital Human Research Center

Goal

The human element is important to almost all industrial systems and products since this element is the targeted benefactor for which they are designed to serve and/or is the critical component whose function determines their performance. For example, a car is for transporting people, and is controlled, mostly, by a driver. Yet, the human element is the least understood within a system. For artificially designed and produced components, advanced mathematical and computerized models have been developed to relate their shape, composition, and functions. In contrast, models of how the highly individual and sophisticated human functions and behaviors are almost nonexistent. In this sense, the human is the "weakest link" in the system.

The goal of Digital Human Research Center is to close this gap. We are developing computational models of the human element, realization of human functions within a computer, with which we can describe, analyze, simulate, and predict human functions and behaviors. Such models are useful for designing and operating systems that interact with humans, so that the systems are more individualized, easier to use, and more harmonious with humans.

The Three Modeling Axes of a Digital Human

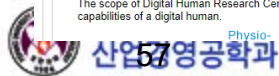
A human exhibits many functions. We classify them into three axes. The first axis is the physio-anatomical function. As a living entity, the human body regulates and controls various parts, organs, and circulatory systems. The physio-anatomical model of human will model the shapes, material properties, physiological parameters, and their relationships to internal and external stimulations. For the Second axis, a human can be regarded as a motion-mechanical machine. A human can walk, run, move, and manipulate objects. The motion-mechanical model will include kinematic, dynamic, and behavioral analysis of human motion. Finally, for the third axis, a human feels, thinks, acts, and interacts. The psycho-cognitive modeling of a human will deal with a human's psychological and cognitive behaviors as they interact with events, other people, and environments.

Naturally, these three modeling axes are not independent. The total digital human will be integration of all of them. We are not necessarily trying to study how humans are built and function at the lowest, natural elements, such as cells, neurons, genes, and proteins. Our main emphasis is the functions themselves: what they are, when they occur, and how they interact.

Three Capabilities of a Digital Human

The computational models may describe human functions, but two additional capabilities are necessary for the study and application of the digital human. First, we need to observe humans precisely, in situ (real environments), and, preferably, in a non-intrusive manner. This includes physiological measurement, motion capture, shape measurement, facial expression analysis, and action inference. In application systems that use the digital human models, such observation technologies provide the input to drive the computational model. When a virtual human interacts with a real human, it must be able to understand the gestures and facial expressions of a real human to properly determine output. In turn, the output of the digital human model must then be presented to the real environment by means of audio, visual, haptic or physical-motion display. These "presentation technologies" range from 3D audio to 3D graphic techniques and from haptic devices to humanoid constructs. The modeling, observation, and presentation technologies are three capabilities of a digital human.

The scope of Digital Human Research Center, therefore, can be summarized in a matrix of the three axes of human functions and the three capabilities of a digital human.



Motion-

Physio-

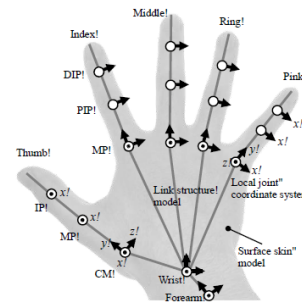


Figure 1. Link structure model and surface model of Dhai-baHand.

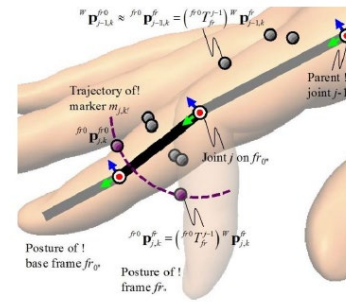
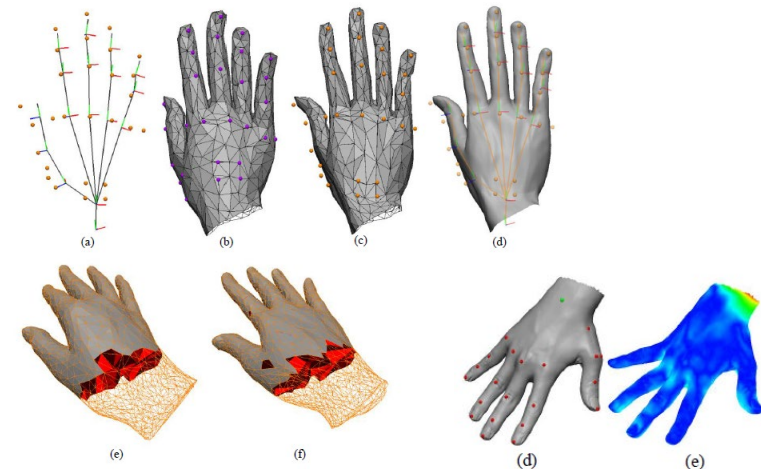


Figure 4. Estimation of joint coordinate system.



Informatik Lab (Max Planck Institute)

- ❑ MPI for intelligent system과는 별개의 연구 그룹으로 CAESAR data 기반 body template model 연구 성과 공유
- ❑ Link: <http://humanshape.mpi-inf.mpg.de/>

MPII Human Shape



Overview Download Examples Contact Publications

Introduction

MPII Human Shape is a family of expressive 3D human body shape models and tools for human shape space building, manipulation and evaluation. Human shape spaces are based on the widely used statistical body representation and learned from the CAESAR dataset, the largest commercially available scan database to date. As preprocessing several thousand scans for learning the models is a challenge in itself, we contribute by developing robust best practice solutions for scan alignment that quantitatively lead to the best learned models. We make the models as well as the tools publicly available. Extensive evaluation shows improved accuracy and generality of our new models, as well as superior performance for human body reconstruction from sparse input data.

Citing this work

```
@article{pishchulin17pr,  
  author = {Leonid Pishchulin and Stefanie Wuhrer and Thomas Helten and Christian Theobalt and Bernt Schiele},  
  title = {Building Statistical Shape Spaces for 3D Human Modeling},  
  journal = {Pattern Recognition},  
  year = {2017}  
}
```

Download

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We are making shape spaces, fitted scans and code freely available for non-commercial and educational purposes only.

Statistical human shape spaces learned from the meshes fitted to the pre-processed CAESAR body scans:

- ⊙ CAESAR (611 MB)
- ⊙ CAESAR + WSX (611 MB)
- ⊙ CAESAR + NH (578 MB)

WSX and NH denote additional posture normalization of the pre-processed scans using the methods of [Wuhrer et al.](#) and [Neophytou & Hilton](#), respectively.

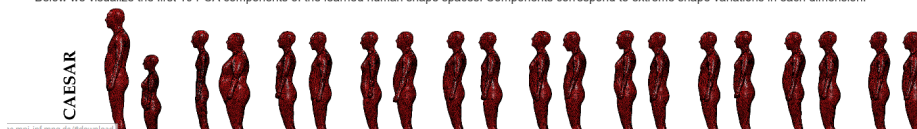
CAESAR-fitted meshes used for learning statistical human shape spaces:

- ⊙ CAESAR fitted meshes (607 MB)
- ⊙ CAESAR + WSX fitted meshes (364 MB)
- ⊙ CAESAR + NH fitted meshes (363 MB)

[Source code \(GitHub\)](#) for data pre-processing, 3D human shape modeling, fitting and evaluation.

Examples

Below we visualize the first 10 PCA components of the learned human shape spaces. Components correspond to extreme shape variations in each dimension.



Hao Li (Univ. of Southern California)

- 3D scan data 처리 분야에 다양한 논문 및 연구 성과 공유
- Pinscreen, Inc., CEO 및 co-founder

Hao Li

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[teaching](#)
[artworks](#)
[CV](#)



黎顯

CEO & Co-Founder
Pinscreen, Inc.

Assistant Professor of Computer Science
University of Southern California

Director of the Vision and Graphics Lab
USC Institute for Creative Technologies








University of Southern California
Department of Computer Science
941 Bloom Walk, SAL 244
Los Angeles, CA 90089-0781


USC - Institute for Creative Technologies
Vision and Graphics Lab
12015 Waterfront Dr.
Playa Vista, CA 90094

Pinscreen, Inc.
12400 Wilshire Blvd., # 1480
Los Angeles, CA 90025


Email: hao@hao-li.com
Facebook: li.hao
Twitter: HaoLi81
LinkedIn: lihao
Home page: www.hao-li.com
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TEDxHollywood




MIT TR 35 video




USC@NYC




VIVID Ideas




faculty talk




full cv




faces - SIGGRAPH Asia 2017




pinscreen




faces - CVPR 2017
featured in fx guide, Gizmodo, Daily Mail, 3ders, and Wired




images - CVPR 2017
featured in reddit, Hacker News, Engadget




faces & VR - SIGGRAPH Asia 2016
featured in vfxblog and USC News




faces - ECCV 2016




body - ECCV 2016



body - CVPR 2016 (Oral)

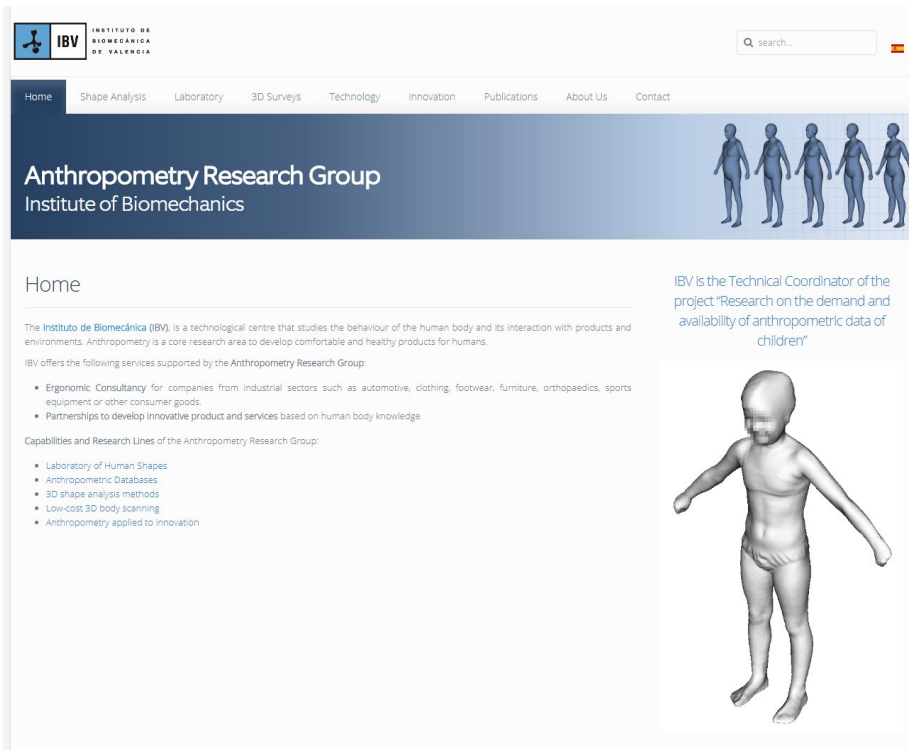


USC - HairSalon



IBV (Instituto de Biomecánica)

- IBV anthropometry research group은 Eurofit project를 비롯하여 body template model 기반 anthropometry 분야에서 다양한 연구 활동을 수행 중
- 상용 application(e.g., Make Human) 개발 및 배포
- Link: <https://anthropometry.ibv.org/en/publications.html>



The screenshot shows the website for the Anthropometry Research Group at the Institute of Biomechanics (IBV). The header includes the IBV logo and a search bar. The main navigation menu lists: Home, Shape Analysis, Laboratory, 3D Surveys, Technology, Innovation, Publications, About Us, and Contact. The main content area features a blue banner with the text "Anthropometry Research Group Institute of Biomechanics" and an image of five stylized human figures. Below this, the "Home" section describes the institute's mission and lists services such as ergonomic consultancy and product development. A 3D model of a child is shown in the center, with text indicating the institute's role as the technical coordinator for a research project on children's anthropometric data.

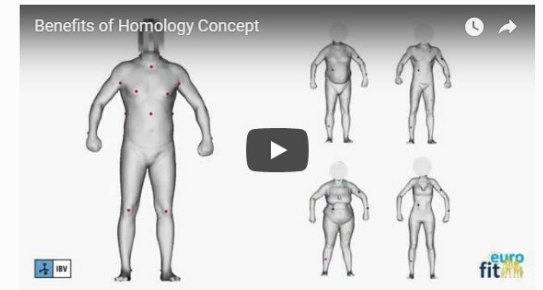
Shape Analysis

Advanced 3D body shape analysis tools

Technology transfer and partnership for the development and application of innovative 3D body shape analysis tools:

- Harmonisation of 3D body raw data
- Accurate and automated creation of homologous avatars and statistics avatars
- 3D avatar generation from body measures
- Digital measuring tape including body dimensions of ISO 7250 and ISO 8559
- Skeleton Rigging and Kinematics Sizing recommendation systems
- Sizing recommendation systems

Homology concept 3D scans to avatars Measurements to avatars Digital tape Statistical avatars



The diagram illustrates the "Benefits of Homology Concept" by showing a central 3D human model with red dots representing key points. Surrounding this are four smaller 3D models of different body types (male and female, thin and thick). A play button icon is overlaid on the central model, suggesting a video or interactive content. The IBV logo and Eurofit logo are visible in the bottom corners of the diagram.

Conducting a shape analysis requires necessary that digital 3D human representations share a common structure to describe shapes. The approach follow the human shape being represented with the same topology. This means that all the 3D shapes are represented by the same number of points and the means there is a point-to-point correspondence.

- Point-to-point correspondence
- Pre-defined and custom body regions
- Pre-defined and custom anatomical body references